

A STUDY OF THE RAT'S BEHAVIOR IN A FIELD

**A CONTRIBUTION TO METHOD IN
COMPARATIVE PSYCHOLOGY**

BY

CALVIN HALL AND E. L. BALLACHEY

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A STUDY OF THE RAT'S BEHAVIOR IN A FIELD A CONTRIBUTION TO METHOD IN COMPARATIVE PSYCHOLOGY*

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CALVIN HALL AND E. L. BALLACHÉY

INTRODUCTION

Comparative psychology in its reaction against the anecdotal dilettantism of the post-evolutionary period has become increasingly insistent upon a quantitative record of performance. Quantification has meant, in large part, a disavowal of the study of that most important psychological datum—the behavior of the animal. The rat in the maze or the discrimination box or the delayed reaction chamber, for example, is limited by the physical set-up to but few responses. These responses are then described by time and error records. Such methods of experimentation and recording, although lending themselves to easy numerical expression, represent but meagerly the rat's actual total behavior.

We shall present in this article observations of the rat's behavior in an open field situation under experimental conditions. It is suggested that by this method one may observe the behavior of the rat under less teleological conditions than are imposed by the usual type of apparatus. By a teleological condition, we mean one in which the rat is forced to behave according to the purposes of the experimenter. We believe that the study of field behavior minimizes the experimenter's purposeful intentions as to how the animal should respond and at the same time makes possible the observation and recording of the rat's true ambulatory behavior under experimental conditions.

* We are indebted to Professor E. C. Tolman for generous counsel during the writing of this article.

The impetus toward the devising of the field method came from the writings of Lewin.^(3, 4) In fact the use of a field for observing rats is but an adoption of Lewin's method for studying children. We were also stimulated by the writings of D. K. Adams⁽¹⁾ and J. A. Gengerelli,⁽²⁾ both of whom have expressed a dissatisfaction with prevailing methods in comparative psychology. Their viewpoints required a new method of studying behavior and this we here endeavor to supply.

The first experiment in which we used the field method and the only one we shall here present was a direct repetition of one of Lewin's experiments on young children. At the Ninth International Congress of Psychology, he reported the behavior of a child a year and one-half old, when confronted by a circular barrier which enclosed a desired object. The child reacted by running around the barrier in a circular fashion. Lewin interpreted this to mean that the direction of behavior would always be perpendicular to the forces (*Kräfte*) emanating from the desired object, and as close to the object as was physically possible. That the child did not describe circles in his running simply because of the circularity of the barrier was demonstrated by another experiment in which the child was placed inside the barrier and the object lay outside. The child then concentrated his activity on that sector of the barrier in the direction of which lay the object.

APPARATUS AND METHOD

The floor plan of the set-up used in this study is reproduced in figure 1. The field was seven feet square and was enclosed by a three-foot wall.¹ In order to enable the experimenter to record the movements of the rat, the field was marked off into foot squares. Over the center of the enclosure hung a 100-watt lamp, lighting the field uniformly. The experiment was conducted in a sound-proof room.

¹ The size of the field can be altered to meet the needs of a particular experiment. The essential principle of the field is that the animal is provided with an open space in which to behave.

A circular covered barrier constructed of wire mesh, one foot in diameter and eighteen inches in height was placed in Square 25 (fig. 1). For Group A, a tin of Steenbock mash was placed in the center of the square enclosed by the barrier. For Group B, the barrier alone was in the field. After each day's run, the floor of the field was brushed in order to control tracking.

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35
36	37	38	39	40	41	42
43	44	45	46	47	48	49

× E

Fig. 1. Floor plan of the field.

× E

× E indicates where experimenters sat.

The rats were introduced into the field at Square 43 with their heads pointed back toward the corner. Five-minute samples of behavior were taken. One experimenter recorded the path of the animal and made behavior notes; the other took active and passive times. The experimenters were seated next to the wall of the field at Squares 43 and 49 (fig. 1), a distance

well beyond the visual capacity of the rat. An attempt was made to eliminate all possible distractions while the rat was in the field.

The rats were twenty-four hours without food when run. The time of running remained constant throughout the experiment; one five-minute sample of behavior was taken each night for each rat. One hour after running, the rats were fed twenty grams of wet Steenbock mash in their home cages.

ANIMALS

The animals used in this experiment were female albino rats from the colony maintained by the Psychological Laboratory, University of California. They were approximately sixty days old when experimentation was started. The rats had had no previous training of any sort in such a field.

RESULTS

GROUP A. FOOD WITHIN THE BARRIER

For purposes of analysis we divided the field into three zones. Those squares which adjoin the four outer walls constitute the outer zone; those enclosing the inner barrier the inner zone; and those which lie between the outer and inner zones the middle zone. Analysis was made in terms of the number of squares in each zone which the rat traversed in successive trials.

The percentages of squares in the three zones traversed by each rat in Group A on successive trials are presented in table 1. It will be seen that the behavior in the inner zone increased for several days to a maximum; then decreased slightly and remained more or less constant. After the first six or seven trials an equal number of inner and outer zone squares were traversed. These percentages reveal two loci of behavior in the field—the outer walls and the inner barrier. The middle zone is traversed only when the rat is running to the inner barrier or to the walls.

But the percentages shown in table 1 do not fully represent the rat's behavior in the field. When the rat is in the outer zone he runs very close to the walls; when he is in the inner zone he circles the barrier. It is impossible to reproduce the paths taken by all the rats from trial to trial. Figures 2, 3, and 4 show three paths of a single rat at different stages of experimentation. The concentric circles should really be thought of

TABLE 1
PERCENTAGE OF SQUARES TRAVERSED IN EACH ZONE
(Group A. Food within Barrier)

Rat	5			6			7			8			10		
Trial	O	M	I	O	M	I	O	M	I	O	M	I	O	M	I
1	100	00	00	97	03	00	81	19	00	80	20	00	49	11	40
2	100	00	00	51	09	40	70	10	20	46	13	41	49	12	39
3	86	06	08	36	19	45	29	11	60	52	12	36	27	21	52
4	80	07	13	31	16	53	34	13	53	42	21	37	41	17	41
5	80	04	16	36	16	48	45	16	39	29	20	51	42	15	43
6	47	06	47	38	17	45	45	19	36	52	14	34	39	18	43
7	80	07	13	43	20	37	41	17	41	43	16	41	55	13	33
8	100	00	00	52	19	29	38	29	33	37	25	39	48	16	35
9	77	08	15	53	14	32	40	18	42	36	22	41	49	15	36
10	74	11	15	44	13	43	52	20	28	51	17	32	49	14	37
11	55	19	26	49	13	38	42	19	40	45	17	38	39	21	40
12	63	15	22	58	19	23	45	09	46	46	19	35	44	17	39
13	52	13	36	48	19	33	41	21	38	50	20	30	48	21	31

O=outer zone; M=middle zone; I=inner zone.

as circular paths immediately around the barrier. Figure 2 represents the path on the second trial when behavior is largely confined to the outer walls. Figure 3 shows the rat's path when circling the barrier has reached a maximum. Figure 4 portrays the rat's behavior when it has reached approximate constancy.

The activity of the rats from trial to trial as measured by the number of squares traversed during the five minutes is shown in table 2. On the average, the rats reach a maximum of activity on the third day and thenceforth become less active. This first sharp rise in activity is directly correlated with the increase in

TABLE 2
TOTAL NUMBER OF SQUARES ENTERED
(Group A)

Trial	5	6	7	8	10	Aver.
1.....	27	86	27	61	104	61
2.....	43	124	103	133	144	109
3.....	140	166	123	176	119	145
4.....	91	155	158	90	123	123
5.....	76	161	105	85	112	108
6.....	83	127	128	86	89	104
7.....	55	107	128	122	86	100
8.....	32	95	106	93	85	82
9.....	74	103	100	116	84	95
10.....	104	86	121	76	76	93
11.....	116	93	114	89	85	99
12.....	54	113	144	84	97	98
13.....	87	73	105	88	62	83

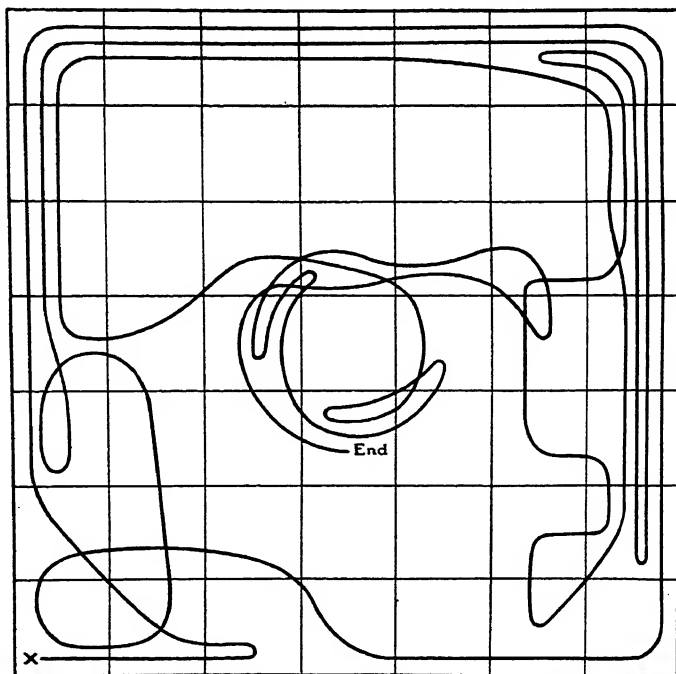


Fig. 2. Path of Rat A7 on the second trial.

behavior within the inner zone. We shall see later when comparing these data with those got from Group B, which was run with no food in the field, that this increased activity is a function of the food within the barrier.

That continuous circling of the barrier is a characteristic of the behavior of the five rats during the first trials is still more

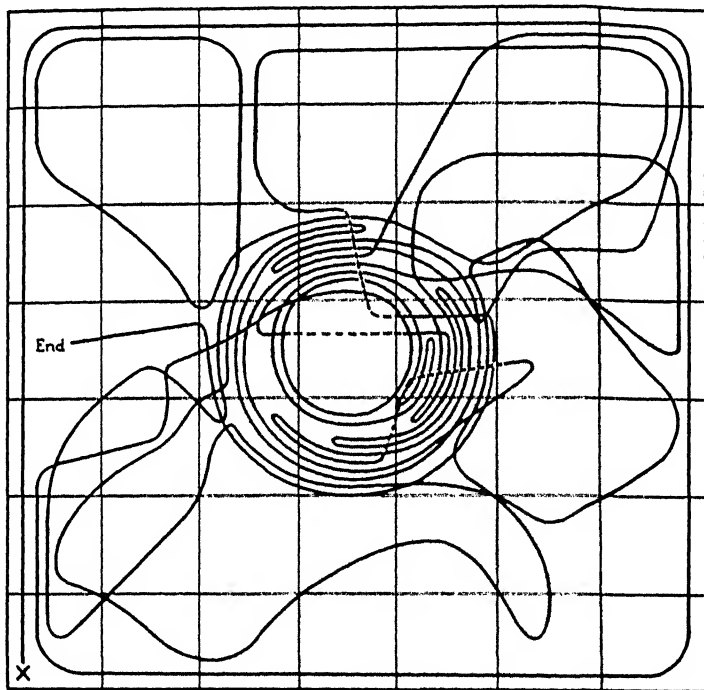


Fig. 3. Path of Rat A7 on the fourth trial.

strikingly brought out by the data presented in table 3. These figures represent the greatest number of inner zone squares traversed continuously on each trial by each rat. That is, the number of squares traversed between each entrance into and each departure from the inner zone was counted. The largest number thus traversed in a given trial by a given rat was taken to make up table 3. For example, rat 10 on day 2 entered the inner zone and traversed thirty-six squares before leaving this zone. He

TABLE 3
GREATEST NUMBER OF INNER ZONE SQUARES TRAVERSED CONTINUOUSLY
(Group A)

Trial	5	6	7	8	10	Aver.
1.....	0	0	0	0	24	5
2.....	0	28	16	39	36	24
3.....	9	10	36	33	19	21
4.....	6	16	29	13	13	15
5.....	12	14	12	20	14	14
6.....	23	23	9	12	15	16
7.....	7	9	15	14	15	12
8.....	0	9	8	12	9	8
9.....	8	10	23	13	11	13
10.....	12	11	9	15	18	13
11.....	8	14	14	10	10	11
12.....	12	10	33	16	13	17
13.....	12	10	7	9	8	9

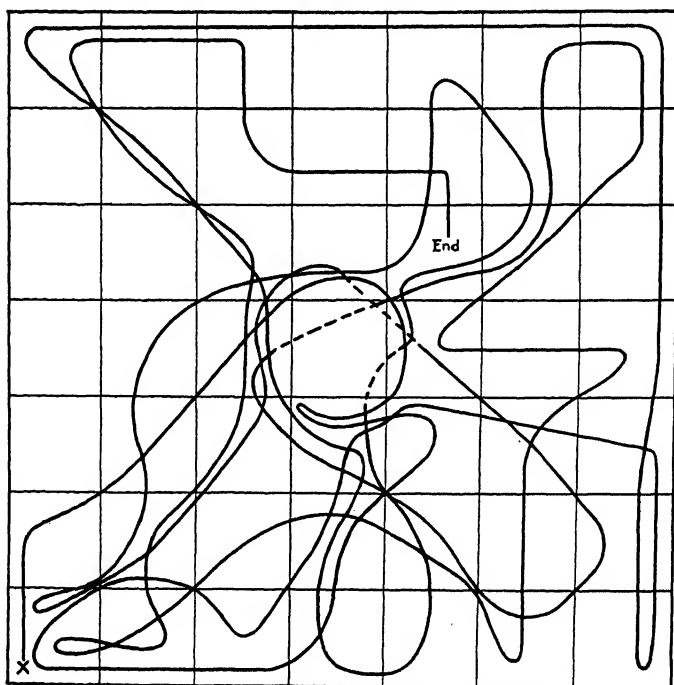


Fig. 4. Path of Rat A7 on the eighth trial.

made other excursions into the inner zone on this day, but never did he stay long enough to traverse more than thirty-six squares. The maximum for the five rats averaged is on the second and third days. These data suggest what our path records demonstrate very clearly—that the rat's behavior at first was marked by continuous running around the walls and then by continuous running around the barrier and that later he alternated more sporadically between the two loci.

GROUP B. NO FOOD WITHIN THE BARRIER

In order to determine whether or not the behavior of the rats in Group A was determined by the food enclosed by the barrier a control group was run. Group B was run under exactly the same conditions as Group A except that food was not present within the barrier.

TABLE 4
PERCENTAGE OF SQUARES TRAVERSED IN EACH ZONE
(Group B, No Food within Barrier)

Rat	17			18			19			20			21		
Trial	O	M	I	O	M	I	O	M	I	O	M	I	O	M	I
1	94	06	00	86	07	07	92	07	01	100	00	00	99	01	00
2	88	09	03	65	12	22	78	10	12	100	00	00	100	00	00
3	79	10	11	76	11	13	78	06	16	100	00	00	100	00	00
4	54	17	29	60	16	22	76	08	16	100	00	00	97	03	00
5	81	09	10	58	14	28	78	06	17	100	00	00	100	00	00
6	53	18	29	66	19	15	79	08	13	100	00	00	100	00	00
7	56	15	29	47	24	28	100	00	00	100	00	00	100	00	00

O=outer zone; M=middle zone; I=inner zone.

The percentage of squares in the three zones traversed by the rats in Group B is shown in table 4. When these figures are compared with those given in table 1, the great difference between the behavior of the rats in the two groups is at once apparent. The percentage of inner zone squares traversed by the rats in Group B did not exceed 29 per cent. It will be

remembered that the percentages of inner zone squares traversed by the rats in Group A was markedly greater. In A 7 the maximum percentage was 60; in rats A 6, A 8, and A 10 it exceeded 50 per cent.

TABLE 5
GREATEST NUMBER OF INNER ZONE SQUARES TRAVERSED CONTINUOUSLY
(Group B)

Trial	17	18	19	20	21	Aver.
1.....	0	5	1	0	0	1
2.....	2	14	8	0	0	5
3.....	4	5	7	0	0	3
4.....	8	6	6	0	0	4
5.....	6	13	9	0	0	6
6.....	11	7	5	0	0	5
7.....	15	9	0	0	0	5

TABLE 6
TOTAL NUMBER OF SQUARES ENTERED
(Group B)

Trial	17	18	19	20	21	Aver.
1.....	93	70	97	56	66	76
2.....	99	107	69	24	1	60
3.....	107	127	67	41	29	74
4.....	124	134	102	27	68	91
5.....	109	153	54	1	17	67
6.....	119	88	52	41	1	60
7.....	134	133	3	29	1	60

Nor did the rats in Group B manifest continuous encircling-the-barrier behavior to any degree as may be seen by consulting table 5.² We may conclude, therefore, that the determiner of

² That the difference between the two groups is a reliable one and not dependent upon a sampling error can be ascertained by computing the standard deviation of the difference. The second and third trials when continuous circling behavior is at a maximum for Group A were averaged and compared with the second and third trials averaged for Group B. The difference is 18.6 ± 5.6 . Such a difference could have occurred by chance 3 times in 100. (The formulae used in this analysis are suitable for small numbers of cases. They were taken from M. Ezekial's *Methods of Correlational Analysis*, pp. 19-20.)

continuous inner zone behavior is the food enclosed by the barrier.

In table 6 are shown the total numbers of squares entered in successive trials by the rats in Group B. That their activity is approximately the same on the first trial as that for Group A is one indication that the two groups are more or less comparable. The marked difference between the two groups from the second trial on indicates that the presence of food in the field exerts a dynamogenic effect upon behavior, increasing significantly the activity of the rats.

CONCLUSION

That the rats circled the barrier and that this was the effect of the presence of food within the barrier verifies Lewin's observations on children. We are not prepared at this time, however, to interpret our results in terms of the concepts of Lewin nor to summarize our data using any other conceptual explanation. A further series of experiments using more animals are in progress to determine whether this behavior depends upon the circularity of the barrier or upon those principles which Lewin invokes to explain the child's behavior. We shall run (1) a satiated group with food in the field; (2) a group placed within the barrier with food at various positions outside; (3) rats who have been fed under the barrier and are then introduced into the field with food within the barrier; and (4) a group fed in the center square and then placed in the field with the food enclosed by the barrier.

But the contribution which we wish to make in this article is not that of substantiating nor of controverting Lewin. It is rather a contribution to methodology; and for purposes of illustration we have merely selected this particular experiment. The advantages of the field method can best be emphasized by contrasting its possibilities with those of the maze.

1. The field method permits the study of the *natural direction* of behavior since it can manifest itself under relatively uncon-

finer conditions. In the maze, the rat's behavior is *artificially directed* by the physical structure of the apparatus.

2. The field method permits more radical changes in the environment than do other techniques. The maze must remain physically a maze but the number of changes which can be made in the field is unlimited.

3. The rat's behavior can be studied over a continuous temporal period. The maze, on the other hand, constitutes a problem or task for the animal and has a fixed beginning and ending.

4. The field method makes possible the use of situations in which learning can be manifested rapidly. "Learning usually and always under the conditions customarily established in experiments on the subject (i.e., puzzle boxes, nonsense syllables and particularly mazes) occurs too slowly for its real nature to be evident." (1, p. 161.)

5. The field method permits the study of the relative attractiveness of various objects. The maze can be used only rather clumsily for such investigations.

6. The field method, finally, is the most satisfactory method for studying what may be considered perhaps the most fundamental determiner of behavior, viz., *the needs of the organism and the effect of these needs on the direction of activity*.

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FIXATION IN THE RAT

BY

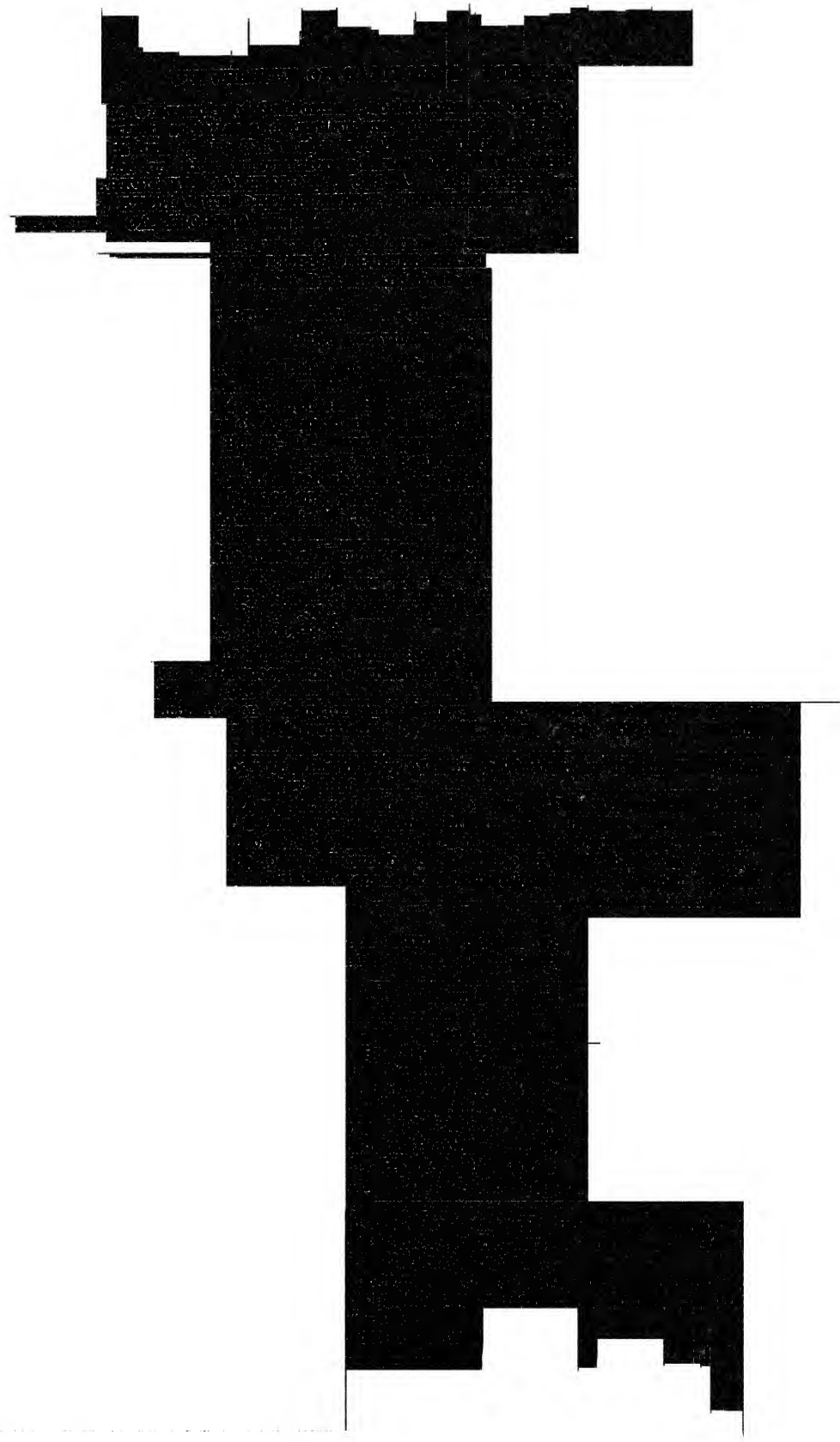
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INTRODUCTION .

Selective frequency as an initiating cause in trial and error learning has been disproved by the experiments of Peterson,^(10, 11, 12) Thorndike,⁽¹³⁾ and others.¹ Excess frequency of the "correct" response at the expense of the "incorrect" can no longer be held as one of the determiners of ordinary trial and error learning.

Further, it has now also been demonstrated by such experiments as those of Higginson,⁽⁶⁾ Hsiao,⁽⁷⁾ Tolman and Honzik,⁽¹⁵⁾ Gengerelli,⁽⁸⁾ Köhler,⁽⁸⁾ Hertz,⁽⁵⁾ and Maier⁽⁹⁾ that in such ordinary learning the learned response is still relatively "insightful," "intelligent," and "plastic" in the sense that, if a change be introduced into the objective situation such that this learned response is no longer "correct," the latter rapidly gives way to some new and more appropriate response.

In a word, frequency does not initiate the ordinary learned response nor does it prevent the latter from giving way rapidly to other more appropriate responses. Tolman⁽¹⁴⁾ has suggested the term "docile" for behavior which is the product of ordinary learning and which is ready to give way rapidly to other behavior if the latter becomes more appropriate.

And Tolman⁽¹⁴⁾ has suggested the term "fixated" for a second type of behavior—viz., a behavior which does not give way rapidly to another more appropriate behavior when the environmental conditions are changed, and he points to the results of Gilhausen⁽²⁾ as perhaps the first experimentally to have isolated

¹ For a brief résumé of all such experiments see Tolman,⁽¹⁴⁾ Chap. XXII.

such "fixated" behavior in rats. More recently Hamilton and Ellis⁽⁴⁾ have also experimentally demonstrated a case of such "fixated behavior" in rats with cortical lesions. They have suggested the term "behavior constancy" for the properties of such fixated behavior.

What are the causes of such fixation or behavior constancy? The ordinary learned act is extremely docile (witness: the experiments of Higginson, Hsiao, Tolman and Honzik, Gengerelli, Köhler, Hertz, and Maier already referred to) in the sense of being potentially changeable when the situation is changed. But here are other "learned" acts which do not have this character. Hamilton and Ellis conclude from their experiments that the tendency toward such fixated acts is strengthened by a lesion in the central nervous system. The possibility has suggested itself to the present writers, however, that a response which was originally docile may become by *excessive frequency* no longer docile but fixated.* If that be so, frequency, far from being unimportant in explaining learning, begins to play again an extremely important rôle.

The purpose of this investigation, more specifically stated, was to determine the effects of three degrees of frequency upon the plasticity of a learned and originally docile response.

APPARATUS AND METHOD

Apparatus.—De Camp,⁽¹⁾ Yoshioka,⁽¹⁷⁾ and others have shown that the white rat is able to discriminate between a long and a short pathway to food and will prefer the shorter. Inasmuch as such a set-up does not *force* the animal to adopt the "correct" solution (since he receives food even if he persists in always choosing the long path) the preference for the short path indicates a cognitive appreciation of the problem (i.e., is "docile" relative to the respective lengths of the two paths).

* We take advantage of the page proof to point out that this same relationship between frequency and fixation had been previously suggested by Gilhausen, who is now attacking the problem with a different experimental set-up (private communication).

With this assumption as the starting point the apparatus shown in figures 1 and 2 was used. These figures present diagrammatic views of the apparatus as it appeared in the two different experimental set-ups used. The animal was permitted to leave his starting box at "S" and enter alley 1, which was a straightaway. C_1 , C_2 , C_3 , and C_4 are black curtains which were suspended from the tops of the maze in such a manner as to prevent the animal from seeing beyond the curtain.

During the experimental runs proper there were no doors or blocks of any kind in the apparatus. When the animal reached the first choice point ("P") he was allowed to turn either to the left and reach the food in box F_L or continue straight ahead and then turn to food box F_s (set-up I, called hereafter position I. For position II the reverse situation held, as can be seen from figure 2).²

It will be seen that in both positions the animal is given an opportunity to take either a short or long path to the food. In position I the path from P to F_s is but half as long as from P to F_L . In position II the shorter path (P to F_s) is but one-eighth as long as the longer path (P to F_L).³ These differences between the length of the short and long paths in both situations are well above the threshold as established by both De Camp and Yoshioka.

Animals.—In all, the records of 40 female rats are presented. Nine of these were pigmented animals and 31 albinos. Of these 40, 30 were selected to make up the three experimental groups used. The basis of selection and the reasons therefor will be given presently.

Preliminary training.—All three groups received the same preliminary training. The "preliminary" period was divided into (1) an "habituation" period and (2) a "pre-test" period. The purpose of the first of these periods was to habituate the animals to the apparatus and to eliminate, as far as possible, all

² A curtain was placed at C_3 in order to equate the two choice points P and P' as nearly as possible.

³ Further dimensions are given in the figures.

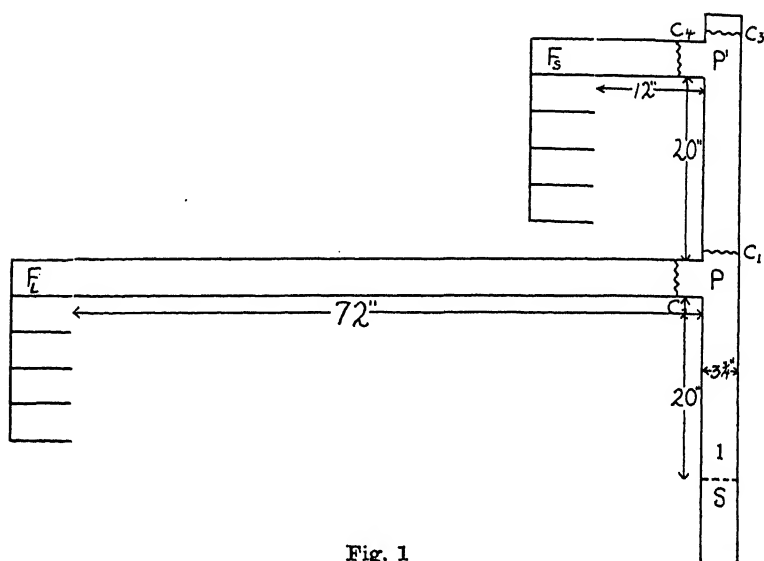


Fig. 1

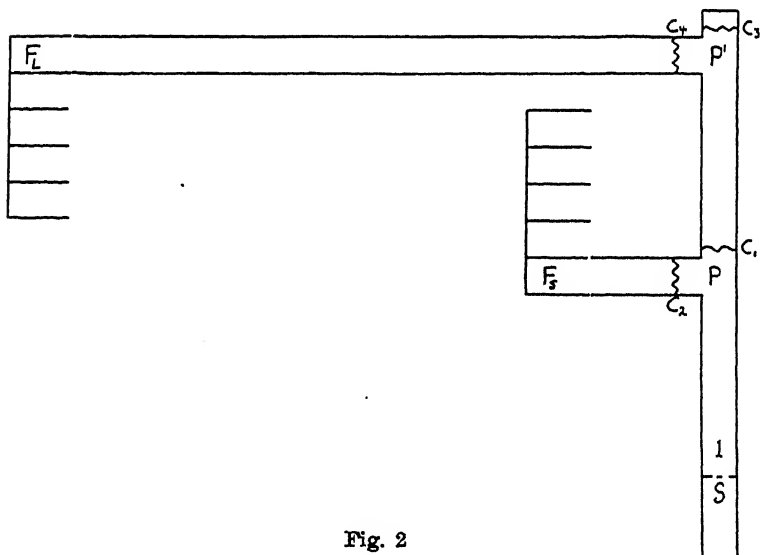


Fig. 2

Figs. 1 and 2. Maze Pattern.

Legend: *S* = Starting point
E = End of maze

interfering emotional behavior. During this period the animals were run through straightaways without elbows, according to the schedule given in table 1.

TABLE 1
SCHEDULE FOR HABITUATION PERIOD

Days	Trials
1	5 runs in 36-inch straightaway
2	5 runs in 36-inch straightaway
3	5 runs in 36-inch straightaway
4	6 runs in 36-inch straightaway
5	6 runs in 36-inch straightaway
6	6 runs in long path of maze, with curtains
7	6 runs in long path of maze, with curtains
8	6 runs in short path of maze, with curtains
9	6 runs in short path of maze, with curtains

Immediately after completing these habituation runs the animals were started on their pre-test training. This consisted of "forced" runs through the apparatus in set-up I (fig. 1). By "forced" run is meant a run where the animal was not allowed to make a choice at point *P*. He found a block behind either curtain *C*₁ or *C*₂ so that he was forced to take either the short or long path according to the position of the block. The paths were so blocked as to force the animal through the short path 17 times and through the long path 17 times. These paths were blocked in a random order. The detailed schedule for the pre-test training series is given in table 2.

TABLE 2
SCHEDULE FOR PRE-TEST PERIOD

Day	Order of Forced Runs	Number of runs
1	L L S L S S	6
2	S L S L S S L	8
3	L S S L S L L S L S	10
4	S S L S L L L S S L	10
	Total.....	34

On the day after the animals had completed their pre-test training the regular experimental runs were begun. During the experimental period proper the following schedule was maintained: each rat was given 12 trials per day, the first two of which were "forced" runs and the next ten, "free" runs. In the first two runs the animal was forced (by blocking off one or the other of the pathways) to run once through the long path and once through the shorter path. The order of "forced" runs was alternated from day to day, i.e., on one day the order would be *L*, *S*; on the next, *S*, *L*. The ten runs following these two forced runs were free in that all blocks were removed and the animal was allowed to reach the food box by either path.

As was said above, both the habituation and pre-test training were the same for all three groups. The length of training during the experimental period proper differed for the three groups.

Experimental training.—The members of all three groups started their experimental runs with the apparatus in position I and were continued in that position until they had met their respective norms of mastery; in the case of Group I (4-day group), the rats were run until 90 per cent of their last 40 "free" runs were choices of either the "long" or "short" pathway. We were not interested in getting every rat to adopt the short pathway, as they might have done eventually if allowed more time, since we wished to have a group all the members of which had about the same degree and length of training. In the case of Group II (8-day group) the rats were run until 90 per cent of their last 80 "free" runs were choices of either the "long" or "short" pathway. And in the case of Group III (12-day group) the same procedure was followed until 90 per cent of their last 120 "free" runs were similarly choices of either the "long" or the "short" pathway.

Then, in each group *only those rats which preferred the short path were continued in position II*. The other rats were dropped. Enough rats were run so as to fill up each group to its quota

of ten. In the following discussion only these "short" rats are considered in referring to each of the groups.

After meeting the norm, on the very next day the rats in each group were set to master the problem as presented in position II* (fig. 2). Here the short path was in the position of the former long path, and vice versa. The animals, in order to solve their problem, were required to *reverse* their former behavior.

They were continued on this problem until they again met the same norm (90 per cent of the last 40, last 80, or last 120 "free" trials either long or short).

The basis upon which we selected the 30 rats from the 40 was, then, the ability of the rats, *in the first instance*, to discriminate between a long and short pathway. That such choosing was necessary is at once obvious when we consider the following facts: Although both De Camp and Yoshioka showed that the "average" rat could discriminate between a long and short pathway, not *all* the rats could do so (within the limits of their experiment). In this investigation we have found the same thing. Twenty-five per cent of the animals used failed to adopt the shorter of the two paths in position I. And since our test situation (position II) required the animal to *reverse* his behavior *in order to reach food by the shorter of two paths*, it would of course have been meaningless to test an animal which could not discriminate, in the first place, between long and short. Such a procedure (i.e., equating groups on the basis of their ability in the particular process), though rare in animal experimentation, is of course a common one in human experiments, where subjects are selected on the basis of intelligence tests and achievement tests.

Another reason for this selection has been suggested above. That is, since we are interested in studying the variable frequency, it would have confused matters to allow some animals many more trials than others in which to master the problem (in this case, adoption of the shorter route).

* The animals were treated individually, that is, each animal was shifted when he himself reached the norm, he was not forced to wait for the whole group to reach the norm.

RESULTS

In considering the performance of the various groups on set-up I (table 3), the first striking fact is the apparent facility shown by the animals which adopted the short path. The average number of errors⁵ for each animal ranged from 5.9 in Group I to 3.7 in Group III. But even these low averages exaggerate the difficulty of the maze, for, actually, these averages are accounted for by the errors made by only a few individuals in each group, and the "n" of each group being so small, they assume too much weight. From an analysis of the individual records it will be seen that nine animals (see table 4) made no errors at all, and some but one or two errors.

This need not necessarily mean, however, that the discrimination involved was extremely easy. It will be remembered that the animals had as many as 34 *forced trials* before their free runs were started and records of errors kept. Much of the learning probably took place before the free runs were started, but one must also remember that the animals were forced down the long path *as often* as down the short path and yet some made no errors at all when allowed a free choice. Certainly the factor of frequency cannot be called upon here to explain this learning.

In general we might point out that all three groups found the first discrimination about equally difficult and therefore came to the first *test* set-up (position II) equal in all respects except in the degree of frequency with which they had performed their original learned response.

In the second set-up (position II, table 4) the three groups diverge one from the other quite definitely.

The animals of Group I (4-day) made a total of 72 errors, where Group II (8-day) made 156 errors, or more than twice as many as Group I, and Group III (12-day), 283 errors, almost *four times as many* as Group I and not quite twice as many as

⁵ In this and the following discussion "error" refers to the choice of the long path.

Group II (table 4). These differences are large enough to assure us, despite the small number of subjects in each group, that the differences are reliable ones.

It might be argued, however, that comparing the total errors of Group I with those of Group II and Group III is unjustifiable since the animals of Group III were given more opportunities to make errors than Group II, and Group II more than Group I. That is, the rats in Group I were run only up to a 4-day norm. Group II 8-day, and Group III 12-day. The differences in errors might then be a function of this variable rather than a function of the difference between the groups.

To meet this criticism the error records for the *first four days for each group* were derived, whereupon the opportunities for errors are equal for all groups. From table 5 it is seen that the status of the three groups respectively to one another remains similar whether we consider the errors made during the first four days, or the total errors made. The differences are still extremely large and equally reliable. Group I has a record of 66 errors, Group II of 124 errors, and Group III of 233 errors. If we consider the number of errors made on the first *eight* days the same results stand. Group II made 156 errors and Group III, 276.⁶

There can be no doubt then that as a result of differential frequency in performing the act learned for position I, the three groups differ in the rapidity and facility with which they can appropriately *change* that learned behavior to fit a changed situation (i.e., "learn" a *new* act). There appears to be an *inverse relationship between frequency and plasticity of behavior*.

Encouraging also is the fact that, although Groups II and III found it *difficult* to shift from their behavior, every rat of both these groups *finally did shift*. In other words, we now have more evidence that these rats *could* differentiate between the two paths and that actually they "preferred" the short path. The test therefore was a fair one.

⁶ Group I cannot of course be considered here because this group had completed the problem before eight days.

TABLE 3
PERFORMANCE OF ALL GROUPS ON POSITION I

Group I		Group II		Group III	
Animals	Errors	Animals	Errors	Animals	Errors
H13	9	W1	2	W12	0
H44	15	W2	1	W13	4
H50	17	W5	20	W14	0
H70	22	W6	4	W16	0
H71	6	W7	2	W17	1
W22	0	W9	0	W18	3
W31	0	W10	1	W20	7
W32	0	W24	5	W21	11
W34	0	W28	2	W26	4
W35	0	W30	2	W27	7
Total	59		48		37
Average	5.9		4.8		3.7

TABLE 4
PERFORMANCE OF ALL GROUPS ON POSITION II

Group I		Group II		Group III	
Animals	Errors	Animals	Errors	Animals	Errors
H13	10	W1	14	W12	4
H44	16	W2	17	W13	27
H50	1	W5	8	W14	20
H70	0	W6	62	W16	40
H71	2	W7	4	W17	42
W22	0	W9	8	W18	39
W31	14	W10	2	W20	53
W32	7	W24	15	W21	16
W34	3	W28	9	W26	21
W35	19	W30	17	W27	21
Total	72		156		283
Average	7.2		15.6		28.3

TABLE 5
ERRORS AT VARIOUS STAGES, ALL GROUPS, POSITION II

	First 4 days	First 8 days	Total
Group I	60		72
Group II	124	156	156
Group III	233	276	283

Although the learning of position II proved to be generally much more difficult for all three groups than the learning of position I (tables 3 and 4) an analysis of the individual's records reveal some surprising results.

Two of the rats in Group I reversed their behavior (i.e., "solved" position II) without making one error⁷ (rats W 22 and H 70), and two rats, H 50 of Group I and W 2 of Group II, made but one error.

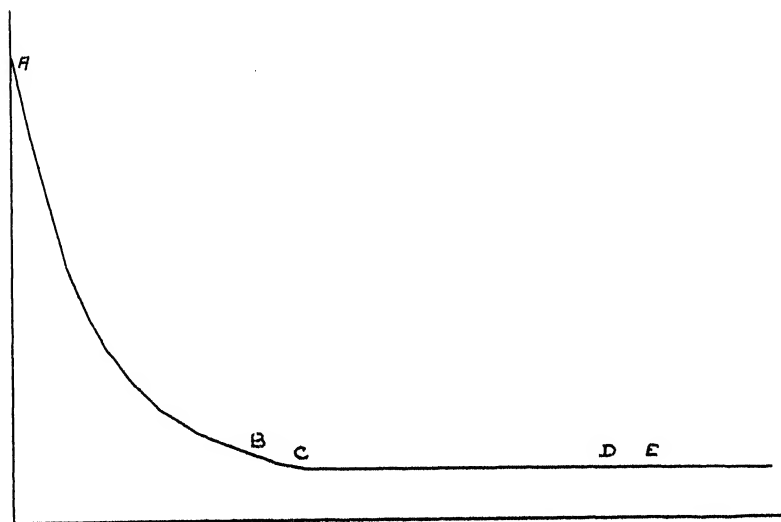


Fig. 3

It is to be noted that, in the case of rats W 22, H 70, H 50, and H 71 (Group I), and W 2 (Group II), the frequency with which they behaved appropriately to position I did not in the least interfere with their reversing that behavior when the situation was reversed. It would be incorrect to say that their last ten runs in position I were a function of frequency and dependent upon frequency for their occurrence, since, when the situation was changed, their behavior changed almost immediately.

⁷ Of course one must remember that these rats were given an opportunity to discover the changed character of the maze by the two preliminary "forced" runs.

DISCUSSION

But we appear now to have two diametrically opposed results. In considering the differences in error scores between Groups I, II, and III, we were forced to conclude that the difference in frequency was an extremely important causal factor. That is, there was an inverse relationship between frequency with which behavior I was indulged in and the speed with which behavior II was learned. In considering, on the other hand, the individual records of Group I in learning problem II, we see just as forcibly that the frequency with which behavior I occurred had nothing to do with the speed of learning position II.

Actually, however, these outcomes are far from being opposed to each other. They require a third and unifying principle. Frequency does not seem to have any effect either in the establishment or continuance of plastic, docile behavior. A learned response, however, which is at first "intelligent" and "insightful" and potentially plastic, apparently becomes *through the operation of frequency* a stereotyped, unintelligent, and insightless response.

The usual way to represent the transformation of uncoordinated behavior into a learned act is, of course, the learning curve. All usual learning curves (fig. 3) have at least two distinct periods. There is the period *A-B*, which represents "learning" as a process, then the level line *B-C* which represents the learned *act*, the result of *A-B*. It is assumed that continuing the behavior of the animals after they had reached their "physiological limit" (at point *C*) would in no vital way change the psychological make-up of the behavior. That is, the behavior at *E* would be the same as at *C*. Yet, in the light of our findings such assumptions are unwarranted. The behavior at *B* or *C* is docile, "insightful" behavior, at *D* or *E*, stereotyped, non-plastic behavior. Psychologically the two behaviors differ tremendously.

We have further seen that this difference is in some degree a function of frequency. Considering our theoretical curve

again, we would say that frequency played no rôle in the period represented on the curve between *A* and *C*, then, somewhere, if the curve is continued, frequency steps in and *D-E* becomes a function of frequency.

As far as external behavior alone is concerned, one could not tell whether the behavior were of the "intelligent" or "fixated" type. That is, the animal running at *E* is doing the very same things as the animal running at *C*. The test to apply to differentiate the two is that of changing the situation. When we do that the behavior of "*C*" type (see record for Group I) changes almost immediately in accordance with the situation, while the behavior of "*E*" type does not change, but remains constant despite the fact that such behavior is no longer appropriate (see record for Group III, table 4).

Frequency, in other words, does not explain *learning*, but rather, *lack* of learning. Frequency does not explain the taking of the short path by the animals of Groups I, II, and III in position I, but it does explain the taking of the *long* path on the part of the rats of Groups II and III (position II).

SUMMARY AND CONCLUSIONS

Three groups of ten animals each were run through a series of two antagonistic long-short discriminations. These three groups were equal in all respects except in the frequency with which they were allowed to perform one learned response before being shifted to the antagonistic discrimination. From a consideration of the records the following conclusions are drawn:

1. Frequency appears to have no causal value in initiating and continuing a learned, docile response.
2. Frequency is one of the causal agencies in transforming a docile response into a "fixated" response.
3. A differentiation is thus made between a learned response which may have all the characteristics of plasticity, docility, and "insightfulness" and a learned response which may lack all these.

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**HYPOTHESES" VERSUS "CHANCE" IN THE
PRE-SOLUTION PERIOD IN SENSORY
DISCRIMINATION-LEARNING**

AND

THE GENESIS OF "HYPOTHESES" IN RATS

BY

I. KRECHEVSKY

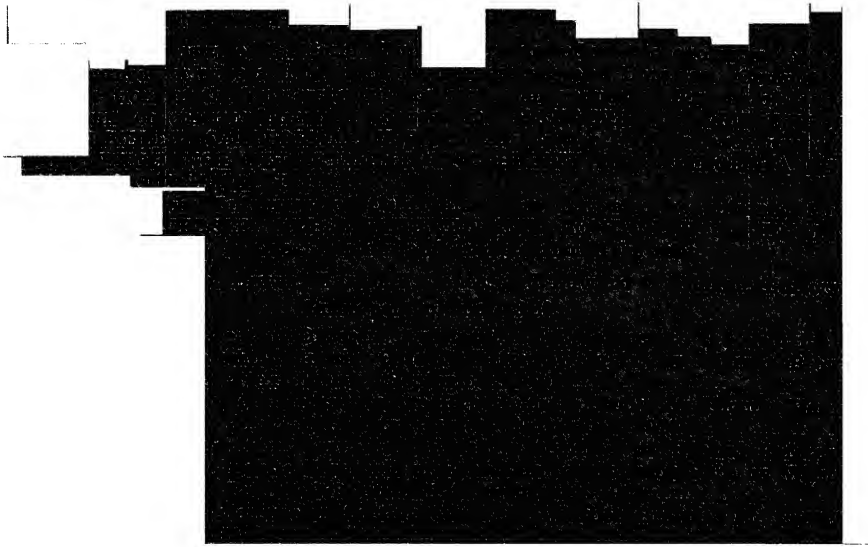
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"HYPOTHESES" VERSUS "CHANCE" IN THE PRE-SOLUTION PERIOD IN SENSORY DISCRIMINATION-LEARNING*

BY

I. KRECHEVSKY

In a previous paper⁽³⁾ it was pointed out that a reexamination of the data obtained from sensory discrimination experiments necessitates the adoption of a new description of learning. It was found that instead of considering the first part of "learning" as consisting of random, haphazard behavior, we must recognize that the animal, during that period, is responding in an orderly, systematic manner. He is attempting various solutions and giving them up when they fail, until he hits finally upon the "correct" one. The present paper presents part of the experimental evidence for such a thesis.

As originally planned and carried out, the experiment involved the setting up of two discrimination habits in each animal—a visual and a "hurdle" habit—as well as a study of the general problem of transfer of training. The present report will concern itself, however, only with that part of the study relevant to this question of hypotheses. And for this purpose the results of the "hurdle" discrimination only will be considered.¹

In his *Brain Mechanisms and Intelligence* Lashley made the first suggestion of a possible relationship between two often observed phenomena connected with the setting up of discrimina-

* Acknowledgments are due Professor T. N. Jenkins, of New York University, under whose supervision this research was carried on, and to Professor Frances Holden for valuable criticism and aid.

¹ A complete report of the experiment is on file at the graduate office of New York University.

tion habits by the white rat—the peculiar shape of the learning curve and the tendency of the animal to form various position habits before mastering the problem. “There are many indications,” he writes,

that . . . in the discrimination box, responses to position, to alternation, or to cues from the experimenter’s movements usually precede the reaction to light and *represent attempted solutions* that are within the rat’s customary range of activity. . . . The form of the learning curve is the more significant when considered in relation to such behavior . . . it suggests that the actual association is formed very quickly and that both the practice preceding and the errors following are irrelevant to the actual formation of the association.²

In other words, even when the “learning curve” appears to show “random” behavior the animal may be responding in a wholly systematic manner. Lashley regrets, however, that “there is no present way to record such behavior objectively and I can present the description only as an impression from the training of several hundred animals in these problems.”³ The data from the present experiment have been examined in the light of Lashley’s suggestion and an attempt has been made to devise a method for the objective determination of the validity of that suggestion.

PROCEDURE

Apparatus—

The apparatus used was a modification of Stone’s multiple-unit discrimination box.⁽⁷⁾ The box consisted of four equal units, each unit presenting to the animal one discrimination and each unit continuous with the other.

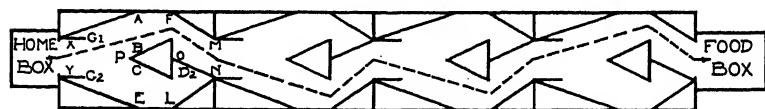


Fig. 1

Figure 1 shows the ground plan for the whole apparatus. The animal is started from a small “home” cage just outside the entrance to the first box. The door, operated by a gravity-

² *Italics mine.* ³ *Ibid.*

string arrangement, opens up into passageway *x-y*. *g1* and *g2* are metal guards serving to force the animal in a straight line toward the stimulus panel *a-c*. The mid-part of the box (*afle*) contains the two stimulus chambers. Triangle *po* is a metal partition which not only serves to separate the two chambers, *ab* and *ce*, but is also so constructed as to prevent any light rays, entering from the second unit through door *mn*, from reaching the animal in the vestibule *g1-g2*. It also serves to prevent the possibility of the animal's detecting the presence of the obstruction (door *d2*) in either of the two alleys.

Door *d2* swings on a pivot at *o*, so that, at the will of the experimenter, alley *ab* or *ce* can become the correct alley and the other, the cul-de-sac. In figure 1 the door is so arranged as to make *ab* the correct alley. When the animal enters the correct alley he is allowed to pass through pathway *mn* and into the next unit where he is presented with the very same situation as in the preceding unit. Immediately after entering the next alley, the door of the next box, corresponding to door *x-y*, is dropped so as to prevent any retracing.

For the most part the floor plan of this box is quite similar to Stone's apparatus except for a few insignificant differences in dimensions. In arranging the stimulus panel, however, a radical departure was made from Stone's apparatus. Figure 2 is a three-dimensional drawing of the stimulus chambers.⁴

In the hurdle discrimination set-up the only differentiating factor between both alleys was the presence of the hurdle. The animal actually had to climb this obstruction in order to gain

⁴ The section labelled *abce* is in the same position as the section similarly labeled in figure 1. In figure 2, *afgb* and *okle* are the two tunnels through which the rat must run. These tunnels are divided into an upper and lower part by a plate of translucent glass at *fg* running parallel with the floor of the box. The upper part contains the electric lights and the lower is the tunnel through which the animal runs. The tops of the two stimulus boxes are covered. Most of the light is directed through the translucent frosted glass plates over the tunnels *afgb* or *okle*, as the case may be; i.e., when the apparatus is used for setting up a brightness discrimination or else, through both tunnels as in the hurdle discrimination. At points *h2*, *3*, *4* and *1*, holes were bored which permitted the insertion of a hurdle at the entrance to either alley, as is indicated in figure 2.

entrance into the alley. The presence of the hurdle was meant to indicate the correct alley, i.e., the hurdle was the positive stimulus. While we are primarily interested here in the hurdle results, perhaps it would be appropriate to discuss this apparatus

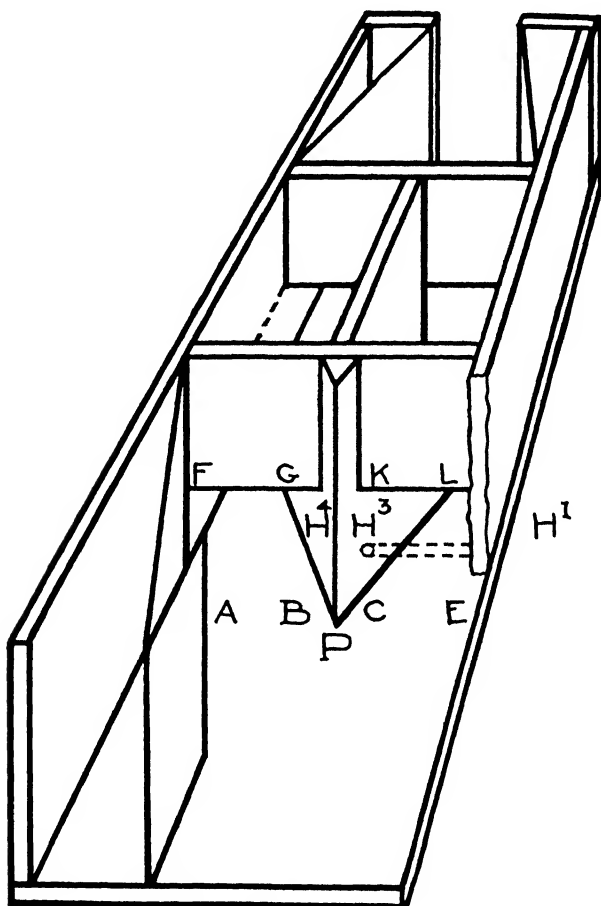


Fig. 2

as used in setting up a brightness discrimination as well, since, in an experiment to be reported later and attacking the same general problem as here presented, brightness discrimination was used with this apparatus.

In making the correct choice (brightness discrimination) the animal is not only forced to go toward the light (as is the case in Stone's box) *but he is actually forced to go into and through the light as well*. This difference in procedure has some theoretical significance and one which, while it seems to be more and more recognized in actual practice, has not yet, by the very experimenters who make use of it, been explicitly acknowledged.⁵

The Gestaltists have been most forward with their criticisms of the usual experimental set-up used in studying animal learning on the ground that too often the animal is required to build up a wholly artificial connection between a given stimulus and a given response, with the result that the consequent performance does not give us a true picture of what the animal can do in a more "natural" and reasonable problem situation. The stimulus, as in the case of the usual discrimination box and as is also the case in Stone's box, is not something that is *intrinsically* connected with either the animal's response or his "reward," it is merely something the experimenter brings *ab extra* and imposes, or wishes the animal to impose, upon the situation. In discussing this very point, Köhler⁽²⁾ writes,

The electric shock, for instance, applied to the legs, is not intimately connected to the task of getting a red spot as "the negative stimulus." There is only a very loose connection between them in space and time. If that spot *itself* would make a sudden movement against the animal and so frighten it . . . we should certainly have a situation much nearer the animal's learning in common life and a more efficient one.

In other words the stimulus, the response, and the consequence should all be intrinsically bound together; the whole should make a meaningful combination. We have some actual experimental evidence to bear out this assertion. Hubbard⁽¹⁾ found that while it took a group of animals an average of 99.3 trials and 29.7 errors to set up a light-dark discrimination when the animals were forced *through* the stimulus, it took another group of animals an average of 174 trials and 56.9 errors to set up a similar habit when the animals could merely travel *toward*

⁵ Since writing this section, a publication of N. L. Munn⁽⁶⁾ has appeared which points out many of the considerations stated below.

the light. Unfortunately the results of that experiment are partly vitiated by the experimenter's failure to control other differences in stimulation between the two groups, such as tactual stimulation, etc., however much the same suggestion is implied in the surprising efficiency of Lashley's new technique for setting up form discrimination habits.⁽⁵⁾ Here, also, the animal is required to jump *through* the stimulus pattern. This very fact may account for the ability of Lashley to demonstrate form discrimination in the white rat where previous experimenters have failed.

The results of this experiment also tend to support Köhler's point. It took the 40 animals an average of but 13 trials and 21 errors to set up a visual discrimination.

It is also apparent that in the hurdle discrimination set-up we have the same desirable situation. Here the animal must not only see the hurdle and travel toward it, but he must also actually *do* something with it. Hurdling the obstacle is an intrinsic and necessary part of the response. The set-up, in general, is one which should encourage rapid discrimination learning.

Animals—

Forty previously untrained male albino rats, about three months of age, were used as subjects.

Method—

No animal was used for experimental purposes until three weeks had elapsed from the time he had been received in the laboratory. Thus every animal was given a period in which to adapt himself to the general laboratory conditions. During these three weeks of acclimitization the animals were fed once a day, at about the same hour that their training series was to be run, in a special feeding cage. Their diet consisted of "McCullum's Mixture" plus a semi-weekly ration of lettuce. Fresh water was always available.

All runs were made at night. A night's work consisted of ten trials per animal. This program was adhered to until the animal satisfied the established norm for learning.

During the runs the experimenter was seated away from the apparatus and was able to observe the behavior of the animal through a series of mirrors which allowed a full view of the box and its contents from one point of observation. The only light in the room, during experimentation, came from within the apparatus itself. Since the top of the apparatus was covered with a fine mesh wire, it would have been almost impossible for the animal to be able to see anything outside of the box. The mirror arrangement also obviated the necessity for the experimenter to move about during the run.

Special care was taken in drawing up the order of presentation of stimuli, to avoid introducing any but chance orders. It will be seen that the situation in this discrimination box is more complicated in this respect than it is in the single-unit discrimination box. In the latter case it is merely necessary that the positive stimulus be on the right as often as on the left, but in the present case it is not only necessary that the total number of stimuli be equated for their position, but also that each unit be equated for that factor. The order of presentation for ten trials is given below.

Trial	1	2	3	4	5	6	7	8	9	10
Unit 1.....	r	l	l	l	r	r	r	l	r	l
Unit 2.....	r	l	r	r	l	l	r	l	l	r
Unit 3.....	l	l	r	r	l	r	l	r	l	r
Unit 4.....	r	r	l	r	l	l	r	l	r	l

This order sufficed for ten trials or for one day's runs. Every day the same order was repeated. It is highly improbable that the rats learned this order, since the series contains 40 items and in no case was any rat presented with the series more than 12 times. Every rat was, of course, given the same series.

At the end of each trial the animal found in his food box a cube of milk-soaked bread. This cube was cut to a predetermined standard size which helped to equate somewhat the reward received by the different animals and the reward received by the same animal from trial to trial. The animal, however, did

not depend upon this diet for maintenance. After he had completed his day's work he was transferred to his feeding cage in the animal room where he was allowed to feed on the balanced ration of "McCullum's Diet" for an hour.

In keeping records of the performance, the following factors were considered: (1) **ERRORS**. An error was counted if the animal inserted his head into the wrong chamber. Complete entry was not necessary.⁶ (2) **POSITION RESPONSES**. Not only was a record made of the animal's response on the basis of the "correct" stimulus, i.e., whether he entered a blind or a true alley, but the side of the box (left or right) was also noted. (3) **NORM FOR LEARNING**. The problem was considered mastered when the animal completed five errorless runs, that is, twenty consecutive errorless discriminations.

RESULTS AND DISCUSSION

In order to obtain significant data in attacking our problem, namely, the relation of the shape of the curve to the various "interfering" position habits, we could not content ourselves with plotting the usual type of curve. The method we finally adopted, and the reasons therefor have been stated in detail in the previous paper,⁽³⁾ but for convenience we might briefly sum up the process here.

After the animals had mastered the discrimination problem the entire performance of each animal was individually analyzed, and the resulting learning curves were individually plotted. For each rat the following items were determined: (1) the number

⁶ Stone⁽⁷⁾ in working with his apparatus isolated three different kinds of errors: (1) advancing into the wrong alley; (2) entering the correct alley, but instead of continuing on into the next unit, retracing back into the same unit; (3) entering the wrong alley but retracing before actually coming into contact with the obstruction. Stone states that he found this third type not definite enough or objective enough to be of any value as different from the first type, and that errors of the second type were so infrequent (another instance of the rapidity with which an animal can build up a general forward-going tendency) as to be of little value. While these three types of errors were also observed in this study the same objections to their consideration were found to hold as in Stone's study.

of "errors" the animal made each day; (2) the number of turns to the left; (3) the number of turns to the right; (4) the number of turns which were in keeping with an "alternating" scheme; and (5) the number of turns in keeping with a "perseverance" scheme.

In considering the resulting curves one must be certain that the locus of any point on any one curve is a significant one. That is, since we are graphing almost every response of the animal it is imaginable that by a certain combination of circumstances some one curve will always appear to show systematic behavior yet actually be a chance fluctuation. To meet this criticism, the extreme limits beyond which chance alone would very rarely send any one curve were determined by the use of the formula $\sigma = \sqrt{\frac{PQ}{N}}$

That is, if chance were the sole determining influence for any one curve, that curve should never go beyond 50 per cent $\pm 3\sigma$. Doing this we find the σ for 40 chances (one day's work) to be 7.8 per cent, which would give, for the extreme limits of chance fluctuations 50 \pm 21.4 per cent, or 28.6 and 71.4 per cent. The graphs have so been constructed as to concern only the upper limit, i.e., 71.4 per cent. This limit, to facilitate inspection of the curve, has been indicated by drawing a line at the proper point across each graph.

Now, if any of the resulting curves should go beyond this limit we can be fairly certain that such a change is owing to some systematic cause. If, therefore, any of the "position" curves go beyond their chance zone limit, while the "error" curve remains on the 50 per cent line we would be justified in saying that, during that period, the animal is responding to the situation in a *systematic spatial* manner; then, if that spatial curve goes back to the 50 per cent line and the "hurdle" curve goes beyond the chance limit and finally reaches 100 per cent efficiency, we have a perfectly objective demonstration of Lashley's suggestion.

We are now ready for a discussion of the actual graphs. Out of the 40 graphs, figures 3 to 6 represent samples of the most clear-cut curves.

In figure 3 we find the rat, for perhaps the first five days, running according to "chance," that is, his "error" score remains well within the pure chance zone; then, during the sixth and seventh days he very rapidly brings his error score down, indicating complete mastery of the problem. A consideration of the broken-line curve, however (the curve representing the animal's turns to the right side of the box), shows that such a description is misleading and entirely untrue. The animal, during the first five days was *not* running by "chance"; the animal, during that period was behaving in a definite, systematic manner, *but on a spatial basis*. During the so-called "chance" period the animal adopted, brought to near-perfection, and then surrendered a perfectly legitimate and unified "attempt at solution." His choices on the basis of the presence or absence of the hurdle represent a second systematic series of responses, which was preceded by a different, but nevertheless just as unified series of responses.

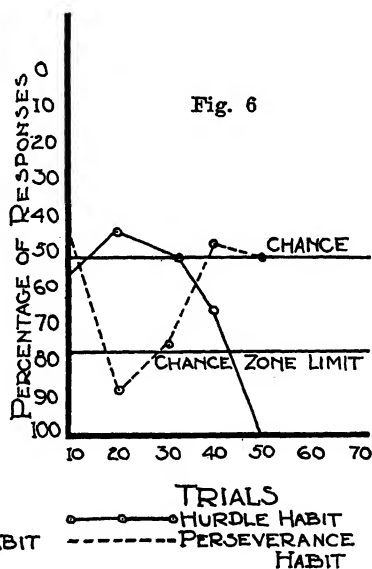
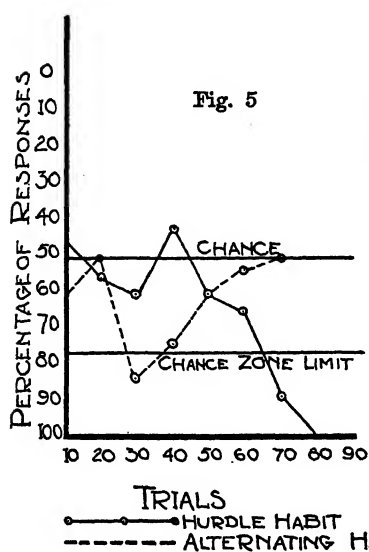
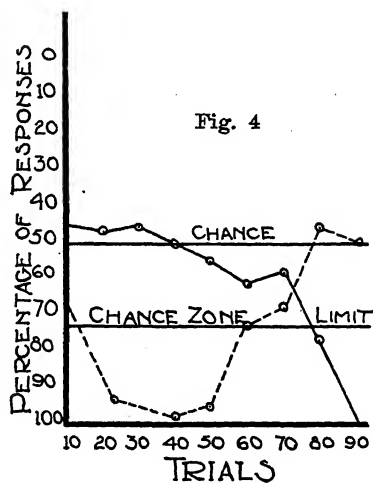
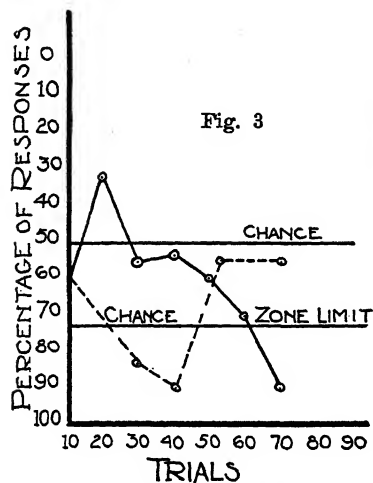
In this specific case then, learning did not consist of haphazard chance responses which finally (through the action of the various Laws of Learning) became systematic, but learning consisted of one systematic series of responses followed by another.

Figure 4 represents the performance of another animal who also happened to show, as a previous "attempt at solution," a right position habit. The implications here are also clear and need no further discussion.

In figures 5 and 6 the "attempted" solutions are an "alternating" and "perseverance" habit respectively.⁷

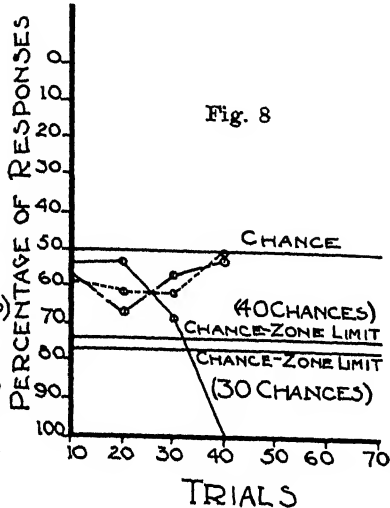
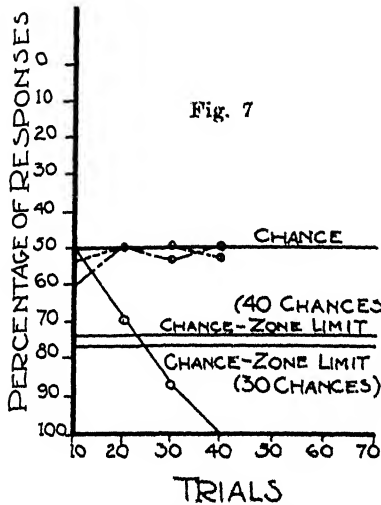
A more detailed analysis of these curves strengthens the suggestion that the interpretation here proposed is a valid one.

⁷ The chance zone for these two habits will, of course, differ slightly from the chance zone for the left or right position habits, because that for the latter habits is based on 40 choices, and that for the former habits on but 30 choices, since the animal's first choice at every trial could neither be considered as "alternating" nor "perseverance." Only the last three choices of each trial were therefore considered. This difference in number of choices gives, as the σ for the last two habits 9 per cent with the limit as 77 per cent instead of 71.4 per cent.



A point that should be noticed in these curves is the close similarity between the rapidity with which the animal builds up his position habit and that with which he builds up his hurdle habit. Thus in figure 3 it took the animal four days to bring his right position habit to the point of greatest efficiency, and it also took him four days to bring the hurdle habit to the same degree of efficiency. (It is obvious that this is so only when we consider the hurdle curve as beginning where the position curve leaves off.) The same is true for the other curves. This striking fact is a further substantiation of the assumption that the adoption of the various position habits is a real phenomenon of the learning act and not some "chance" epi-phenomenon; as real, at any rate, as is the adoption of the hurdle discrimination by the rat, the same organism showing in either behavior the same characteristics of speed and efficiency.

Another point to be made is in relation to the "difficulty" of a discrimination problem and the resulting shape of the learning curve. It may be pointed out that the "typical" discrimination curve is obtained only where the discrimination involved is a more or less difficult one; where the problem is "easy" no such curve results. We can see, from our proposed relationship between the shape of the curve and the animals' adoption of the various position habits, why one should expect that very thing. We call that discrimination problem "easy" for the animal which requires but a few trials for its establishment. In order to establish any sensory discrimination habit rapidly the animal must "pay attention to" ("react to") the correct stimulus from the very outset. That would mean that the experimental situations were of such nature as to make outstanding and most obvious the "correct" stimulus. This would further mean that the animal's first "attempted solution" was the correct one and therefore an analysis of his performance would reveal no other systematic "attempted solutions," with the result that his "error" curve would never remain on the 50 per cent line, but would show the same characteristics as the maze-learning curve, i.e., steady improvement.



—○—○—○ HURDLE HABIT
 - - -○- - -○- - -○ RIGHT POSITION HABIT
 —○—○—○ ALTERNATING HABIT

—○—○—○ HURDLE HABIT
 - - -○- - -○- - -○ RIGHT POSITION HAB.
 —○—○—○ PERSEVERANCE HABIT

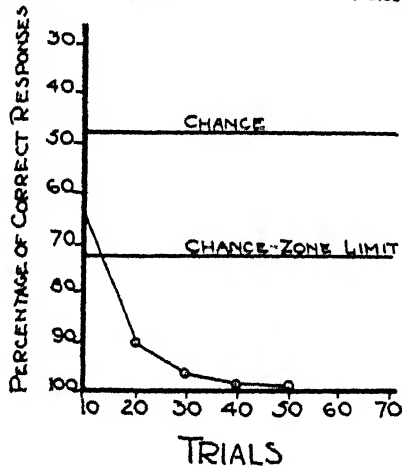


Fig. 9

Figure 7 shows a concrete example of the argument proposed above. Here the curve for the hurdle habit is atypical, it does not show the usual picture, but rather resembles more closely the curve obtained from the light-dark discrimination (see fig. 9), the "easy" discrimination. It appears that here the animal "hit upon" the correct stimulus from almost the very beginning with the result that he solved the problem with extreme rapidity. This would mean, according to the interpretation suggested above, that the animal did not at first attempt other "wrong" solutions as, for example, spatial solutions. That is exactly what happened. The two curves representing the four possible position habits stay very close to the 50 per cent line, although they are not forced to do so by virtue of the locus of the hurdle curve. In other words it would have been possible, statistically considered, for the two position curves to go well beyond the 50 per cent line at the same time that the hurdle curve was at the 70 per cent line; nevertheless they failed to do so, the animal was not attempting a position solution.

It was remarked above, when introducing our curves, that we were reproducing only some of the most clear-cut ones. Not all of the remaining curves show quite the same things as those which we have reproduced. Out of the 40 curves, perhaps 15 are of the very same type as illustrated in figures 3 to 6 inclusive. The others are more confusing in implications. In figure 8 we have an example of a curve which does not fit in with our description of the others. While this curve is of the positively accelerated type, and in that respect shows a similarity to the others, nevertheless the curves representing the *position habits* for this animal do not show the same characteristics as the other curves; none of the four possible position habits going beyond a chance fluctuation. This curve, and it must be admitted there are a number of them, need not be interpreted however as contradictory to our general thesis. As a matter of fact, a close analysis of these very curves strengthens our hypothesis. Regarding figure 8 more closely it will be seen that while neither the right position habit nor the perseverance habit ever get beyond the

chance zone, the two curves do depart a little from the 50 per cent line, and depart from that line at the same time. On the second day both curves reach their maximum together. This suggests that at any one time (that is, over the space of one day's trials) the animal was responding not to one position habit, but to two, alternately. Further analysis proves this to be quite a tenable view. Upon inspecting the animal's individual responses more closely it was found that of *the ten responses* (on the second day) *which did not fit in with the perseverance scheme eight were choices to the right!* Every time the animal departed from his perseverance scheme he went to the right side of the box. Only two times out of all 40 possibilities did he make a response which fitted in with neither "hypothesis."⁸ This vacillation on the part of the rat, between a perseverance habit and a right position habit, would prevent the curve representing either habit from reaching a point outside the chance zone. Such behavior, however, is not different from the other behavior we have analyzed. In this case the animal, instead of making but one systematic attempt at solution before hitting upon the correct one, tries several, and each for a short period of time only. Even in these curves then, we fail to find room for haphazard and non-unified behavior patterns existing at many points of the learning process.

An analysis such as has just been made lays itself open to serious statistical criticisms. Essentially what we have done, the argument may be, is that by considering *every* response as part of some systematic form of behavior, we have of course eliminated, *ipso facto*, the possibility of finding any "chance" responses. Such a criticism is difficult to meet here. All our learning curves are so short as to make it impossible to deal with our data in the statistical manner required in order to prove that our *combinations* of these various position habits do not lead to artifacts, but are statistically justified. In another experiment, the report of which follows on pages 45-64 of this volume,

⁸ For the use of the term "hypothesis" to describe these various "attempts at solution" see our introductory paper "Hypotheses in Rats" (3).

the set-up was one which gave us longer learning curves and more data with the result that we were able to demonstrate quite definitely the validity of our method of combining the responses.

Throughout this paper we have been forced to present the data of individual animals only. Nowhere have we been able to call upon group results. The reason for this is obvious. An analysis such as we have made here would be impossible if we were to content ourselves with obtaining hypothetical averages of the hypothetical average rat and draw hypothetical learning curves. We feel that real and valid information in reference to the behavior of organisms can be obtained only by studying the actual individual as an individual. Such a method however has the obvious drawback of appearing non-quantitative in nature. We have attempted to devise some manner of presenting these results as group results. The value of such procedure is to suggest that the behavior, of which up to now we have merely given samples, is universal for the white rat.

The evidence is shown in table 1. This table was constructed in the following manner: The curve for each rat was surveyed, noting for each position habit the lowest point on the curve.

TABLE 1
PERCENTAGES OF MAXIMAL EFFICIENCY REACHED BY ANIMALS IN
BUILDING UP POSITION HABITS

Habit	71-75	76-80	81-85	86-90	91-95	95-100
Right	2	5	3	4	..	1
Left	3	1	1	..	..	..
Perseverative	4	2	..	1	..	..
Alternating	3	2	4	..	..	..
TOTAL	12	10	8	5	..	1

(Thus for rat #810-C, figure 6, the lowest point for the perseverance habit would be 87 per cent; for rat 51-D, figure 8, the lowest point for the right position habit would be 62 per cent and for the perseverance habit, 67 per cent, and so forth.) In table 1 are presented the frequency of occurrences of these points

for the four possible position habits. Thus, five curves (from all 40) reached the 76–80 per cent line of efficiency for the right position habit, etc. *It will be seen that in all there are 36 cases of position-habit-curves going beyond the line allowed by chance (73 per cent); twelve of these reaching an efficiency between 71 and 75 per cent; ten, between 76 and 80; and 14 between 81 and 100 per cent. In other words, the tendency to build up a systematic series of responses during the so-called period of chance is characteristic of most of the rats studied in this experiment.*

CONCLUSIONS

The characteristic form of the learning curve obtained in setting up discrimination problems was investigated in relation to the animal's tendency to form various position habits prior to mastery of the discrimination habit. Objective and quantitative evidence is presented of Lashley's suggestion that such position habits represent "attempted solutions" on the part of the rat, and it is shown quite definitely that during that part of the learning performance, which is represented on the usual curve by an almost horizontal line at the 50 per cent point indicating no improvement, the animal is engaged in bringing to perfection various attempted solutions. After each "wrong" solution is discarded in turn, the animal attempts another until he finally hits upon the "correct" one. Four different such spatial "attempts" at solution were isolated, a right-going habit, a left-going habit, a perseverance habit, and an alternating habit. The 40 animals used as subjects showed a total of 36 such habits before finally adopting the "correct" response, a hurdle discrimination.

In the light of all the evidence presented here it is suggested that helter-skelter unorganized trial and error response as a description of the early part of the learning process is invalid, and that we must change our description of the learning process so as to recognize the existence of organized and systematic responses at *all* stages of the process.

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THE GENESIS OF “HYPOTHESES”
IN RATS

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THE GENESIS OF "HYPOTHESES" IN RATS*

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I. KRECHEVSKY

INTRODUCTION

In previous papers^(1, 2) the thesis was developed that the learning process consists of a series of systematic responses. In the light of certain experimental results it was proposed to regard the first part of the learning process as consisting in unified, meaningful and purposive behavior. The term "hypotheses" was proposed for these early systematic responses. This term carries with it certain desirable theoretical implications. One of these implications is that an "hypothesis" is an individual's *contribution* to the objective stimulus-field. That is, an "hypothesis" is not a resultant merely of the actual, immediately presented stimuli, but also owes some of its genesis to the reacting individual himself.

This paper presents in detail the second set of experimental evidence cited in the first paper.⁽¹⁾ The method of obtaining crucial data in the present experiment was to offer the animals an unsolvable problem, in the sense that no one stimulus occurred systematically with the "correct" alley. Any *differential* response to the situation and the stimuli therein would therefore have to be initiated, partly at least, by the animal himself. In other words, the presence of systematic forms of behavior in such a situation is to be interpreted to mean that these systems were determined not as something forced *ab extra* by the situation, but as something originating from the animal himself.

* This is the third of a series of investigations on the pre-solution behavior of the animal in the learning situation. We wish to acknowledge our indebtedness to Professor Edward C. Tolman and Dr. Robert C. Tryon for advice and criticism.

APPARATUS AND PROCEDURE

The apparatus has already been described in the second paper.⁽²⁾ Briefly, it consisted of a four-unit discrimination box so constructed as to force the animal *through* the various sensor stimuli which were employed (fig. 1). Extreme precautions were taken in setting up the experimental situation so as to eliminate all extraneous cues.

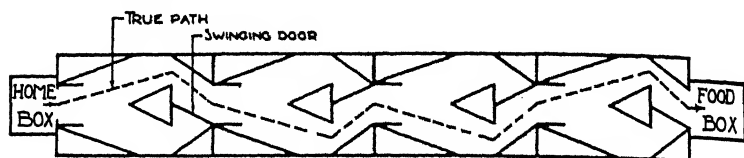


Fig. 1.

Nine previously untrained rats were run in this experiment. Of these nine animals, five were pure albino males, obtained from the regular stock of the University of California psychological laboratory; the other four, also males, were pigmented rats obtained from F₂ generation of Tryon's "dull" race of rats.

As far as could be determined the health of the animals was satisfactory throughout the experiment and at no time did the animals appear to be sluggish or unmotivated. The animals were fed, besides the "reward" which they received at the end of each trial, a modified Steenbock diet.

All rats were given two weeks of preliminary training before beginning the experiment. The preliminary training consisted of feeding the animals once a day (at the same hour as the experimental runs were to be given) in the food box of the apparatus.

¹ These animals have been bred for "dullness" in maze performance. That such breeding is possible is simply demonstrated by the significant studies of Tryon (5).

² The reward consisted of a constant sized cube of bread soaked in a rich milk. This form of reward permitted a fairly constant amount of food after every trial, a factor which is extremely important when it is necessary, as it was in this experiment, that every performance of the animal be equally rewarded.

The actual experimental situation consisted of presenting to the rats the usual brightness discrimination set-up, i.e., one alley darkened and one alley lighted, but instead of arranging the apparatus so as to allow the animal eventually to solve the problem, no opportunity was given the animal to associate the light or the dark with the "correctness" of the alley. Sometimes the lighted alley was the open one, sometimes the darkened; sometimes the alley on the right, and sometimes the alley on the left. No matter which form of consistent behavior the animal adopted he would find himself blocked at least 50 per cent of the time.³

SCHEDULE A

Trial	1	2	3	4	5	6	7	8	9	10	11	12
Unit 1.....	r	R	l	L	R	l	R	r	L	l	r	L
Unit 2.....	L	l	R	r	R	L	r	l	l	r	L	R
Unit 3.....	R	R	r	l	L	r	L	L	l	R	r	l
Unit 4.....	L	r	R	l	L	r	l	L	r	l	R	R

Explanation.—The letters indicate the position of the lighted alley, "L" for left and "R" for right. A capital letter indicates that the lighted alley was the open one; a small letter, that the lighted alley was the blocked one. For example, in the first trial the lights were arranged in a right-left-right-left order, but in the first unit the open door was on the *left*, in the second on the left, in the third on the right, and in the fourth on the left again.

The animals were given 12 trials per day for 14 days. Since each trial meant four discriminations, a record of 672 discriminations per rat was obtained.⁴

³ Schedule A gives the order of presentation of stimuli. The order as it is shown in the schedule is one which makes *every* unit of the apparatus equal in the following essential respects: (1) the number of times the lighted alley is correct is equal to the number of times the darkened alley is correct; (2) the number of times the lighted-open alley is on the right side of the box is equal to the number of times the lighted-open alley is on the left side of the box; (3) the same is true for the darkened-open alley, the lighted-closed alley, and the darkened-closed alley; (4) the number of times the darkened-or-lighted-open alley is on the same side of the box as the open alley in the preceding unit is equal to the number of times it is on the opposite side. (In this connection see habits Nos. 3 and 7 below, p. 5.) Thus for each unit no one stimulus-relationship is favored.

⁴ The first 12 trials were divided over a period of two days. That is, on the first day the animals were given only half their trials and on the second day, the other half. Starting with the third day each animal ran through a full day's schedule. Thus actually the animals were run for 15 days.

In our previous work four different systematic types responses were found, any one of which the animal might attempt when placed in the discrimination box. These four responses were: (1) a right position habit, (2) a left position habit, (3) perseverance habit, and (4) an alternating habit. In this experiment, where we are testing for the presence of *any* systematic behavior on the part of the rat, the more reaction possibilities we investigate the closer we should be able to get a real understanding of the behaving animal. From a consideration of the experimental set-up and from an observation of various phases of the animal's behavior in the apparatus, the three following "habits" were added to our list of possibilities: (5) a light-going habit, (6) a dark-going habit, and (7) a visual-perseverance habit.⁵ These last three habits are visual ones and together with the four spatial ones mentioned above taken in, perhaps, many of the responses that the animal might adopt. It would be unwarranted, however, to assume that this list completely exhausts the possibilities of systematic behavior on the part of the animal.

The method of analyzing the data was to go over each day's responses of each animal and record the number of these responses which were in keeping with each of the above possibilities. Then, if the animal was, at any time, behaving in any systematic manner, we would at once become aware of that fact through the daily inspection of all the habit scores.

It was stated above that the stimuli were so arranged as to favor none of the above mentioned possibilities. The animal, therefore, if he depended upon chance, or if he ran in an aimless and chance fashion, should have made none of these responses more than 50 per cent of the time on any one day. If, however, the animal's score for any one habit *exceeded* the score expected by chance we would be justified in assuming that the animal was

⁵ By a "visual perseverance" habit is meant one where the animal in any unit (except the very first one) enters that alley which is of the same *brightness* as the open alley of the just preceding unit. For example, if the animal discovers that in unit 1 the dark alley is the "correct" or open alley, then, when he gets in unit 2 he should enter (to have his response credited as a visual-perseverance one) the dark alley. In unit 3 he should enter that alley (light or dark) which he found open in unit 2.

responding in a *systematic* manner. For the sake of convenience in analyzing the data, all the scores for each animal were translated into curves (see fig. 2).

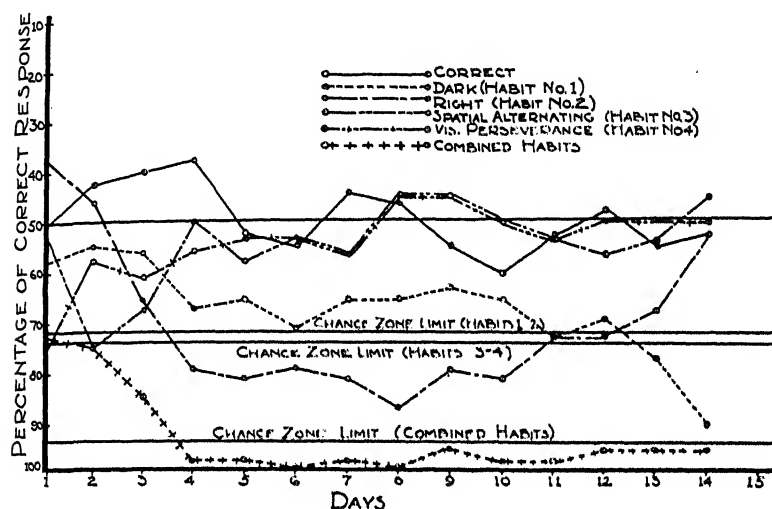


Fig. 2

To make certain that we did not ascribe any significance to a chance fluctuation, the limits were determined beyond which any one of the possible curves would very rarely go if chance alone were operating. This was done by the use of the formula

$SD = \sqrt{\frac{PQ}{N}}$. Any curve, therefore, that went beyond 50 per cent $\pm 3\sigma$, we felt fairly certain was not to be attributed to chance but rather as signifying the presence of some systematic cause forcing the animal's behavior

In figure 2 can be seen one of the resulting graphs. The different curves represent the different possible systematic habits; the horizontal lines at the 50 per cent point and various other percentage points indicate the upper "chance-zone" limit for the various possibilities.

The analysis of the data, as made throughout the experiment, is applicable to individual performances only. It would be mean-

ingless to attempt to draw a "group" curve; the only thing to do would be to present the individual curve for each rat. Such a procedure is undesirable on practical grounds, and so, instead of presenting the data in graphic form, the data for each rat are presented in tabular form in such a way as to allow the reader to follow the rat's performance day by day and see just what the rat was doing each day. Tables 1 through 8 present these data. Under the appropriate headings the percentage of responses that the animal made each day for the various habits are indicated.^a

TABLE 1
RAT W2

Day	Correct choice	Dark choice	Right choice	Combined habit
1	46	62	50	83
2	46	58	67	87
3	46	58	69	85
4	38	62	83	98
5	46	54	88	94
6	42	62	71	92
7	48	60	69	92
8	52	48	77	87
9	54	58	87	98
10	56	48	81	92
11	52	48	81	90
12	44	52	90	96
13	56	52	85	94
14	52	52	90	98

Total responses—672.

Choices to right—521.

Choices to left—151.*

Choices to dark—373.

Choices to light—299.

* Of these 151, 56 or 37 per cent were *left-Light*.

^a Only those data are here reproduced which concern habits persisted in a significant number of times. That is, if the animal *never* made better than 50 per cent on a given habit, that habit is not considered in these tables.

TABLE 2

RAT W6

Day	Correct choice	Dark choice	Right choice	Spatial Alternate choice	Visual Problem choice	Combined habits
1.....	50	58	38	53	75	73
2.....	42	54	46	75	58	75
3.....	40	56	65	67	61	85
4.....	38	67	79	50	56	98
5.....	52	65	81	58	53	98
6.....	54	71	79	53	53	100
7.....	44	65	81	56	56	98
8.....	46	65	87	44	44	100
9.....	54	62	79	44	44	96
10.....	60	65	81	50	50	98
11.....	52	73	73	53	53	98
12.....	48	69	73	56	50	96
13.....	54	77	67	53	50	96
14.....	52	80	52	44	50	96

Total responses—672.

Choices to right—471.

Choices to dark—449.

Choices to left—201.*

Choices to light—223.

* Of these 201, 45 or 22.3 per cent were *Left-Light*.

TABLE 3

RAT W7

Day	Correct choice	Dark choice	Right choice	Combined habit
1	46	67	58	87
2	40	60	69	90
3	35	77	60	94
4	44	67	50	83
5	46	79	67	98
6	42	79	54	92
7	46	71	71	96
8	54	71	79	100
9	54	62	87	100
10	52	52	98	100
11	48	62	90	100
12	50	50	100	100
13	50	50	100	100
14	50	50	100	100

Total responses—672.

Choices to right—520.

Choices to dark—431.

Choices to left—152.*

Choices to light—241.

* Of these 152, 29 or 19 per cent were *Light-Left*.

TABLE 4
RAT W8

Day	Correct choice	Dark choice	Right choice	Combined habit
1	48	52	60	81
2	50	50	100	100
3	50	50	100	100
4	52	50	83	92
5	52	56	90	98
6	50	67	85	100
7	52	73	77	100
8	52	73	77	100
9	48	69	81	100
10	48	73	77	100
11	46	71	79	100
12	60	69	81	100
13	54	75	75	100
14	44	69	81	100

Total responses—672.

Choices to right—551.

Choices to dark—430.

Choices to left—121.*

Choices to light—242.

* Of these 121, 14 or 11.5 per cent were *Light-Left*.TABLE 5
RAT W9

Day	Correct choice	Dark choice	Right choice	Combined habit
1	44	52	60	81
2	50	54	75	90
3	52	73	56	90
4	46	71	71	96
5	40	60	87	98
6	50	50	100	100
7	50	50	100	100
8	50	50	100	100
9	50	52	98	98
10	50	50	100	100
11	50	50	100	100
12	52	52	98	100
13	50	50	100	100
14	50	54	92	98

Total responses—672.

Choices to right—593.

Choices to dark—369.

Choices to left—79.*

Choices to light—303.

* Of these 79, 24 or 30.3 per cent were *Light-Left*.

TABLE 6

RAT H58*

Day	Correct choice	Left choice	Day	Correct choice	Left choice
1	44	69	8	54	98
2	46	92	9	50	96
3	50	96	10	50	100
4	56	94	11	50	96
5	50	100	12	50	100
6	54	96	13	50	100
7	52	94	14	50	100

* Since this animal showed but one habit there are no data for his "combined habits."

TABLE 7

RAT H69

Day	Correct choice	Dark choice	Left choice	Combined habit
1	62	67	50	83
2	44	56	65	85
3	35	48	27*	62
4	60	69	44	81
5	52	98	48	98
6	50	92	56	100
7	56	85	65	100
8	48	81	69	100
9	58	75	71	98
10	50	92	58	100
11	48	81	60	96
12	48	81	60	96
13	52	79	60	96
14	48	69	69	94

Total responses—672.

Choices to dark—515.

Choices to light—157.†

Choices to left—385.

Choices to right—287.

* A right position habit.

† Of these 157, 53 or 33.7 per cent were *Light-Right*.

TABLE 8
RAT H73

Day	Correct choice	Dark choice	Left choice	Combined habit
1	58	54	54	79
2	54	73	46	83
3	48	69	60	90
4	46	79	38	85
5	52	81	56	94
6	50	87	58	98
7	52	65	77	96
8	52	73	77	100
9	50	83	67	100
10	52	73	73	98
11	50	83	67	100
12	48	77	69	98
13	46	79	67	98
14	50	87	62	100

Total responses—672.

Choices to dark—511.

Choices to left—418.

Choices to light—161.*

Choices to right—254.

* Of these 161, 39 or 24.2 per cent were *Light-Right*.TABLE 9
RAT H74

Day	Correct choice	Dark choice	Right choice	Combined habit
1	52	73	44	83
2	50	77	71	98
3	48	69	77	98
4	52	73	69	96
5	48	85	65	100
6	54	83	67	100
7	52	81	65	98
8	46	75	71	98
9	60	85	60	98
10	48	90	60	100
11	54	75	75	100
12	52	85	65	100
13	50	75	75	100
14	56	85	65	100

Total responses—672.

Choices to dark—534.

Choices to right—445.

Choices to light—138.*

Choices to left—227.

* Of these 138, 15 or 10.9 per cent were *Light-Left*.

When the percentage of responses *exceed* the percentage that might be expected by chance (50 per cent $\pm 3\sigma$) the entry is made in italics. Thus an entry in italics opposite any one day and under any given rubric indicates that on that particular day the animal was responding in the indicated *systematic* manner. (In both the curve and the tables some data are labeled "Combined habits." These data are explained in detail on page 58.)

The first striking fact that stands out from an observation of these individual records is that *every animal established at least one definite "habit"; not one animal showed "chance" responses.* In table 10⁷ these habits have been summed up and it is seen that almost every rat adopted not *one* but *two* habits, while one rat (No. 6) adopted *four* different habits during the experimental period.

Of the eighteen habits adopted by the animals ten were spatial, and eight, visual. While this is rather an even division it would be inaccurate to suppose that the animals showed no preference for either kind of response or habit. Some of the animals seemed to definitely prefer a visual habit (H69, H73, H74) while some rats preferred a spatial habit (W2, W6, W7, W8, W9 and H58).⁸ In other words, while all the rats might have adopted, at some time or other, both a visual and spatial habit, one of these was persisted in decidedly more frequently than the other (see tables 1 to 9).

Such definite individual preferences undoubtedly result from something other than chance. We have, unfortunately, not enough animals here to treat the two preference groups as such and attempt to correlate these performances with any other factors, but it is significant that all three of the animals which preferred a *visual* habit were pigmented animals and animals whose ancestors were notoriously *poor* on *maze* performances.⁹ The animals which preferred the *spatial* habit were albinos and

⁷ The data for this table were derived by noting for each animal the particular habit or habits which showed at any time a greater frequency than chance (50 per cent $\pm 3\sigma$) expectations.

⁸ An "H" indicates a pigmented animal and a "W," an albino.

⁹ Tryon (5).

supposedly rats of average maze ability. The case is of course not so clear-cut as one might wish since one of the pigmented animals (H58) also preferred the spatial solution. Further, the number of cases is altogether too small to justify any extended treatment of these aspects of the data, but they do suggest some extremely interesting possibilities and open up new avenues of experimental approach to the problem of the genesis of behavior patterns. We shall here indicate merely one possibility.

The animals which preferred a non-spatial solution of the problem (i.e., those which adopted a *visual* one) were animals which, arguing from the records of their ancestors, would be poor in spatial performance. (The reader is again referred to Tryon's report.⁽⁵⁾) Having pigmented eyes, they would be better *visual* animals than the albinos, as Robinson and Wever⁽⁶⁾ have shown. When placed in a situation which allowed them to establish *any* habit such animals adopt a "visual" one; whereas the other animals, being better "spatial" and worse "visual" animals *in the very same situation under the influence of the very same external stimuli* adopt *spatial* habits. This argues at once for the hypothesis that the behavior of the animal was not a product of, and was not initiated by the immediately presented situation only, but rather that the adoption of orderly, systematic responses represents an *interpretation* of the data presented, a personal interpretation which is a function of the animal's past experience, genetic make-up, and physiological equipment. The external environment does *not* "work" upon a passive and neutral organism, rather, *the organism works upon the environment*.

This conclusion, however, does not need to rest upon the meager data just discussed. The very fact that every animal adopted a uniform response shows at once the inaccuracy of ascribing to the external environment all responsibility for initiating systematic behavior. The environment was so controlled here as to make it ineffective in forcing any orderly series of responses. Yet, despite this, despite the fact that the "laws" of frequency, intensity, and effect were given no chance to work,

every animal quite definitely adopted and brought to perfection at least one systematic habit.

A greater insight into the rats' behavior can be obtained by considering individual performances. The animal, as a rule, adopted one habit, persisted in it for a while, gave it up, and adopted a second habit, and in some cases a third and a fourth.

Thus I173 first adopted a dark-going response which he maintained for about five days, then, suddenly, he adopted a left-going habit, for a day, then went back to the dark-going habit. But perhaps the best illustration of such behavior is that of W6 (table 2). On his first day he adopted a visual-preservance habit, on the second day, a spatial-alternating habit, then, for nine days, a right-going habit, and for his last two days, a dark-going habit (see here fig. 2 also for a more graphic representation than table 2). There can be no doubt, then, that a systematic and unified series of responses can be initiated by the animal himself *in spite* of his environment.¹⁰

In looking through the individual records one sees again and again an apparently improbable fact. On some days it would seem that the animal is responding to a spatial habit *and* to a visual habit. Thus the record of I174, on the eleventh day, indicates that 75 per cent of his responses were made on the basis of a right position habit and 75 per cent of his responses, on a

¹⁰ An hypothesis such as is outlined here does not throw overboard the environment. When we say that an animal can adopt a systematic response "in spite of his environment" we do not imply that the animal can so behave *in vacuo*. The environment is an essential part to consider when describing the animal's behavior, but to assume that the environment is of primary importance and that the immediately presented stimuli are responsible for the *initiation* of behavior is, we believe, inaccurate. Probably the first psychologist to point out the possible differentiation between stimuli as *initiating* behavior and stimuli "*supporting*" behavior (which is essentially the differentiation which we are trying to make) is E. C. Tolman. Tolman, in his *Purposive Behavior in Animals and Men*, elaborates upon this distinction which has apparently escaped earlier recognition. "A rat," writes Tolman, "... in a discrimination-box ... cannot 'choose' the white side from the black without actual whites and blacks continuously to *support and verify* such a choice."⁽⁴⁾ In other words, while the *choosing*, the *behaving*, is not *initiated* by the blacks and whites, still, unless the blacks and whites were there, the animal could not so behave. The environment determines which, of all the behavior-units the animal *can* apply (a priori to experiencing this environment) he shall apply. This is giving to the environment a *limiting* function and not an *initiating* function.

dark-going habit. Seventy-five per cent is of sufficient magnitude to assure us that neither of these responses was a chance one. The explanation is of course simple and obvious, but the implications that follow are of extreme significance.

These two kinds of responses, spatial and visual, overlap in many cases. For example, in entering a darkened alley which is on the right side of the box, the animal is at the very same time responding in both a visual and spatial manner. Thus the animal might pile up his score for either kind of habit. But, in order to show as high a percentage of consistency as 75 per cent in *both* responses, the animal can make no entrances, or very few, into a *lighted* alley which is on the *left side*; for such a response, if made significantly frequent, would prohibit either of the other habits from reaching 75 per cent. What this means is that every time the animal departed from his dark-going habit he did so only to enter an alley on the right side of the box; never did he depart from his visual habit to enter an alley on the left side. In other words it may be that *on any one day the animal may have been responding not on the basis of one habit but two habits, a visual and a spatial one.*

Detailed examination of the animal's responses shows that such was actually the case. Under the column "Combined habits" is shown, for each day, the percentage of responses which fitted in with either of the two dominant habits that the animal may have had at the time. Thus for rat H74 on day eleven, *every* response which the animal made was either a turn to the right or an entrance into a dark alley. His combined score is 100 per cent. This cannot be a "chance" result, since chance would lead us to expect that of the 12 times the rat departed from his dark-going response, 6 of them should have been entrances into the *lighted-left*, and 6 into the *lighted-right*; or of the 12 times he departed from the right position habit, 6 of them should have been into the *lighted-left* and 6 into the *darkened-left*. Of course the number of cases is so small as to allow one to argue that by chance all 12 *happened* to be on the left side, and that no significance should be attached to that

fact. If, however, one considers the history of the animal's responses (where it is at once seen that the animal seemed to prefer the right side and the dark alley throughout), such a criticism becomes improbable. But we do not have to depend upon that. If we consider *all* 672 responses of the animal we can prove beyond doubt that the argument of chance cannot hold. Of the 672 responses, 534 were to the dark and 138 to the light. Chance would then require that of these 138 times when the animal did depart from the light, 50 per cent of them (or 69 responses) should have been to the left. As a matter of fact *only 10.9 per cent* (or 15 responses) were to the left. Here the numbers are large enough to assure us that the animal was *not* making chance responses whenever he departed from his light-going habit. A similar analysis for every other rat reveals the same thing. (The reader is referred to tables 1 through 9 and especially to the footnotes to these tables.)

This fact is brought out even more convincingly if we group several animals together. It will be seen from the individual records that six animals (W2, W6, W7, W8, W9, and I174) showed as their dominant habits a dark- and a right-going response. If we treat these animals as one group we find that *of the total of 4,032 responses only 183 (or 4.5 per cent) did not fit in with either "hypothesis" of the rat* (table 11). Of the 1446 responses which the animals made, which were not in keeping with the dark habit, only 12.6 per cent were entrances into the left-lighted; where, if these non-dark responses were chance responses, we should have expected 50 per cent of them to be left-light.

The same thing holds true for the two rats which adopted for their habits a dark-going and a left-going habit. Their records, treated in the same way, show that out of the total of 1,344 responses only 92 (6.8 per cent) fitted in with neither habit. Of the 318 times that the two animals chose the light, only 28 per cent were turns to the left (table 12).

TABLE 10
HABITS ADOPTED BY ANIMALS

Rat	Dark	Right	Left	Spatial alternate	Visual perseverance	Tot
W2.....		x				1
W6.....	x	x		x	x	4
W7.....	x	x				2
W8.....	x	x				2
W9.....	x	x				2
H58.....			x			1
H69.....	x		x			2
H73.....	x		x			2
H74.....	x	x				2
Total.....	7	6	3	1	1	18

Visual habits—8.

Spatial habits—10.

TABLE 11
"DARK" AND "RIGHT" HABIT GROUP

Rat	Dominant habits		Light choice	Left choice	Light-Left choice
	Dark choice	Right choice			
W2	373	521	200	151	56
W6	449	471	223	201	45
W7	431	520	241	152	29
W8	430	551	242	121	14
W9	369	593	303	79	24
H74	534	445	138	227	15
Total	2586	3101	1446†	931‡	183*

* Of total responses (4032) only 4.5 per cent (i.e., 183) did not fit in with either of the two dominant "hypotheses."

† Of 1446 responses that were not in accordance with the dark-going habit, only 12.6 per cent were to the left where 50 per cent should have resulted if these non-dark responses were "chance" responses.

‡ Of 931 responses which were not in conformity to the right-going habit, only 19.6 per cent were to the light whereas 50 per cent should have resulted if chance determined these 931 responses.

TABLE 12
 "DARK" AND "LEFT" HABIT GROUP

Rat	Dominant habits		Light choice	Right choice	Light-Right choice
	Dark choice	Left choice			
H69	515	385	157	287	53
H73	511	418	161	254	39
Total	1026	803	318†	541‡	92*

* Of the total number of responses (1344) only 6.8 per cent (or 92 choices) fitted in with neither the dark nor left habits.

† Of 318 choices not in keeping with the dark habit only 28.9 per cent were to the right where 50 per cent would have resulted had these 318 been chance divergences from the "dark" habits.

‡ Of these 541 choices to the right (not in keeping with the left habit) only 17 per cent were to the light. Here again chance would have required 50 per cent.

There can be no doubt that the score given in the "combined-habit" column really represents a valid fact and not an artifact. That is, it might be argued, as was pointed out in a previous paper,⁽²⁾ that by calling *every* response a "systematic" one and by *combining* all these various "systematic" responses we could have *ipso facto* no "chance" responses left. A detailed examination has shown that these "combined" scores represent two scores which are not chance scores in themselves, but which are results of two definite causes. It is necessary, however, to determine the maximum "combined" score we could expect by chance for any one day. This is quite easily done by the

formula $\sigma = \sqrt{\frac{PQ}{N}}$. Let us assume a special case where the

combined score consists of the scores for a dark-going habit and a left-going habit. Chance would force the animal to enter the dark alleys 50 per cent of the time, but of this 50 per cent, 25 per cent would be turns to the right, and 25 per cent turns to the left. If now we calculate the combined score for this chance animal (dark responses plus left responses), we would credit him with 50 per cent for the dark responses plus 25 per cent for the left responses, or a total of 75 per cent for the

combined score.¹¹ This is the expected chance score for combination of any two habits (that is, any spatial and visual habit). Substituting this value in the above form

we get $\sigma = \sqrt{\frac{.75 \cdot .25}{48}}$; $\sigma = .062$; $3\sigma = .186$. If then any "c

bined" score for any one day exceeds 93.6 per cent ($75 +$ we can be fairly certain that that combined score represents *systematic* behavior on the animal's part.

These combined scores have more significance than to prove that an animal may be responding to more than one "hypothesis" on any given day. They further substantiate the theory that during the entire performance of the animal there are very few unsystematic, random, chance responses. For example: during the fifth and sixth day is obviously responding to a dark-going habit; on the eighth day and thereafter the animal is just as obviously responding to a right position habit; but on the seventh day it appears that the animal is responding to neither habit and is running in a chance and aimless fashion, for neither his dark- nor right-going habits occur frequently enough to assure us that they are more than chance fluctuations. If, however, we examine the combined score for that day we find that only 4 per cent (or 2 chances out of the 48) were to the *light* or *left* side of the box. In other words, this day represents a transition period in the animals' behavior. He is dropping the visual habit and assuming the spatial habit, but neither habit is dominant as yet over the other; the animal vacillates between the two, but in any case, the animal is *not* running by chance.

It appears that we would probably be justified in saying that at *no* time does the animal run by chance. When our data do not entirely support such an inclusive statement it is probably because of the lack of a sufficiently fine method of analysis.¹² V

¹¹ It must be remembered that this is 75 per cent of the *total* number of possibilities. This is not the same as the per cents we have been dealing with in our previous discussions, where the possibilities were only those trials in which the animal departed from any given habit.

¹² It must also be noted that our standards in differentiating between "true" and "chance" scores have been most rigid: 3 sigma. This means

have seen throughout that the finer and more detailed we make our examination of the data, the less and less does the animal appear to be a "chance" animal. It would be a gratuitous assumption to suppose that we now have a complete insight into all of the animal's behavior possibilities.

We may very well find that our older descriptions of the lower animals' behavior as consisting of "stereotyped," "haphazard," "non-insightful" responses are to be attributed not to a lack of insight on the animals' part but rather to a lack of insight on the experimenter's part.

CONCLUSIONS

Nine animals were presented with a situation so controlled as to remove any possibility that the factors, frequency, recency, and effect, might cause the animal to adopt any definite form of response. Despite this all the animals adopted one, and in most cases more than one, systematic, uniformed form of response. From a consideration of these results the following points are made:

1. The rat, when placed in an unsolvable situation, does not respond in a helter-skelter chance fashion, but makes a series of integrated, unified attempts at solution.

2. These systematic responses are partly, at least, initiated by the animal himself and are not altogether merely a resultant of the immediately presented external situation.

very well obscure some of our results, for some of the scores which fall just below 50 per cent $\pm 3\sigma$, may not be owing to chance at all, although we have, to be more certain of our data, so labeled them.

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THE EFFECT OF REMOVAL OF REWARD ON THE MAZE PERFORMANCE OF RATS. II AND III

BY

ROBERT HALL BRUCE

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THE EFFECT OF REMOVAL OF REWARD ON THE MAZE PERFORMANCE OF RATS. II*

BY

ROBERT HALL BRUCE

In Study I (volume 4, pp. 203-214) it was found that, when the reward was removed after a training period of ten days in a square maze, there was a significant increase in distance and in time. After 13 days of such continued running of the maze without receiving food, deprivation of food for 42 hours, instead of the usual 18, caused a still larger increase in excess distance and in time.

FORTY- EIGHT HOUR GROUP

(Group 3)

In the present study the performance just summarized is compared to that of a group that had been run and fed every 48 hours. As a secondary check a new food box with food in it was introduced for days ten, eleven, and twelve, to see if the mere difference of the food box would affect maze performance, irrespective of the presence or absence of reward. The same maze and general technique were used as in the previous study.

* Professor Edward C. Tolman and Professor Warner Brown, of the University of California, were generous of advice and criticism while the experiment was in progress. Professor Samuel Renshaw and Professor Francis L. Landacre, of the Ohio State University, as well as Professor Tolman kindly criticized the manuscript. I should also like to acknowledge the kind assistance of Mr. Elmer Royer who assisted in the statistical work, and Mr. Frank Stanton who prepared the graphs.

DETAILS OF PROCEDURE

Group 1, an experimental group, was composed of 12 rats, 6 hooded and 6 albino. It was run and fed every 24 hours; the food reward for this group was removed after the tenth daily trial, when the curve of learning had become relatively stable. Since the animals could not know that food was to be removed on the eleventh day, the performance on this eleventh day belongs with that on the first ten days. Group 2, serving as control for Group 1, was composed of 7 hooded and 7 albino rats. These rats were run and fed every 24 hours throughout the 26 days of the experiment. Group 1 and Group 2 are, respectively, the "experimental" and "control" groups of the previous study. Group 3, a second experimental group composed of 24 albino rats, was run and fed every 48 hours. All the animals of Group 3 had the food reward removed on the fourteenth day of running (the curve of learning then indicating a relatively stable level of performance). The performance on this fourteenth day is to be counted with that of the preceding 13 days, since again the animals could not know that on the fourteenth day that they were to receive no food.

All rats were males and approximately three months old at the beginning of training. After any run each rat was confined approximately 12 minutes in an individual food compartment. Groups 1 and 2, run every 24 hours, received the normal ration but Group 3, run every 48 hours, received double this ration as it was not fed again until it had completed its next run 48 hours later.

In addition, there was one "double-hungry" day when groups 1 and 3 were kept an added 24-hour period without food, a total of 42 hours for Group 1 and of 66 for Group 3, and were then placed in the maze. The 42 and 66-hour interims are explained by the fact that during the non-reward period the animals were fed 6 hours after being taken out of the maze. This "double hunger" occurred on trial 24 for Group 1 and on trial 20 for Group 3. To serve as an experimental check to see whether a new food box in itself, without

a change in reward conditions, would modify maze performance, a new box with food in it, was used with one-half of Group 3 (i.e., Group 3*a*) on trials 11, 12, and 13; while with the other half of the group (Group 3*b*) the food box was not changed.

RESULTS

1. *Results previous to removal of reward.*—All three groups showed a normal learning curve, but the 48-hour group, Group 3, did consistently more running about in the maze, and took proportionately more time in so doing. That there was really an extra

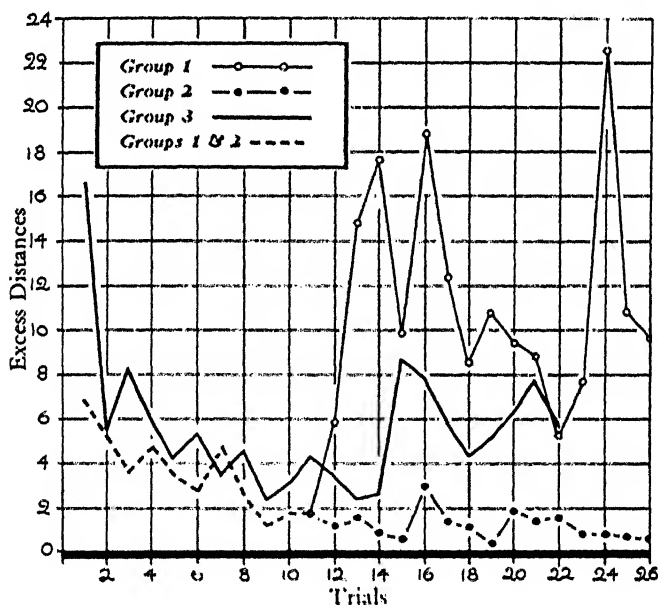


Fig. 1. Excess distance per Rat

excess distance for Group 3 as compared with Groups 1 and 2, is shown by the fact that while the averages of the percentages of long paths taken to the food box show a difference between the 24 and 48-hour groups of only 5.4 per cent, the averages of excess dis-

tance covered by the two groups show a difference of 2.189 units of excess distance for the 48-hour group. This can be seen by inspection of figures 1 and 3 and table 1.

TABLE 1

Days	Average excess distance per rat		Average time in seconds per rat		Percentage of rats taking long path				
	Groups 1 and 2 24 hours	Group 3 48 hours	Groups 1 and 2 24 hours	Group 3 48 hours	Groups 1 and 2 24 hours	Group 3 48 hours			
1	6.83	16.73	130.5	652.4	58.6	50.0			
2	5.16	5.42	46.5	60.4	52.2	50.0			
3	3.69	8.13	25.3	82.3	25.2	50.0			
4	4.70	5.80	37.3	42.6	43.4	41.5			
5	3.59	4.13	25.5	30.9	35.3	71.0			
6	2.79	5.25	23.6	37.3	42.3	33.5			
7	4.67	3.42	26.3	24.3	61.9	41.5			
8	2.62	4.50	32.5	22.7	31.2	50.0			
9	1.29	2.34	15.3	15.5	27.3	37.5			
10	1.79	3.00	14.1	21.4	27.0	25.0			
11	1.76	4.25	12.4	20.8	27.3	41.5			
Food removed (Group 1)	Group 1	Group 2	Group 1	Group 2	Group 1	Group 2			
12	5.91	1.14	3.46	48.48	9.31	23.6	25.0	29.0	52.5
13	14.91	1.42	2.34	231.0	7.07	13.3	33.3	29.0	37.5
14	17.16	.85	2.50	225.25	7.42	29.6	83.4	21.3	29.0
Food removed (Group 3)									
15	9.91	.57	8.71	69.54	4.55	64.8	41.6	13.8	41.5
16	18.91	2.92	7.88	216.96	9.77	105.7	66.6	50.0	23.5
17	12.34	1.42	5.84	114.48	10.88	57.8	66.6	35.5	58.5
18	8.41	1.14	4.21	186.16	7.31	49.4	50.0	35.5	37.5
19	10.75	.28	5.00	90.93	3.95	46.3	41.6	66.6	54.5
20	9.41	1.85	*6.23	108.90	7.48	*142.1	66.6	42.9	*33.5
21	8.91	1.42	7.75	117.13	5.31	145.2	50.0	29.0	45.5
22	5.33	1.57	5.79	63.03	7.12	131.0	33.3	21.3	
23	7.66	.85		104.73	5.41		58.4	21.3	
24	*22.5	.85		*286.6	4.51		*58.4	21.3	
25	10.91	.85		206.16	4.8		66.6	21.3	
26	9.66	.78		400.58	6.72		58.4	13.8	

* Double hungry.

2. *Results when food box was changed.*—When the different food box on days 11, 12, and 13 was used in the maze for Group 3a, food was still found by the animals at the end of each run. An

TABLE 2
PERFORMANCE WHEN FOOD BOX WAS CHANGED

Trial	Excess distance per rat		Time in seconds per rat	
	Box changed	Box not changed	Box changed	Box not changed
	Group 3a	Group 3b	Group 3a	Group 3b
7.....	3.67	3.17	29.2	24.3
8.....	3.50	5.58	20.1	22.7
9.....	1.50	3.17	14.9	15.5
10.....	3.17	2.83	24.2	21.4
Change (Group 3a)				
11.....	2.50	6.0	16.8	20.8
12.....	5.42	1.5	39.4	23.6
13.....	3.67	1.0	16.6	13.6

TABLE 3
COMPARISON BETWEEN MEANS OF GROUPS 3a AND 3b WHEN A DIFFERENT FOOD BOX, CONTAINING FOOD, WAS SUBSTITUTED*

n=24 Trials	Excess distance			Time		
	11	12	13	11	12	13
Group 3a	2.50	5.42	3.67	16.8	39.4	16.6
Group 3b.....	6.00	1.50	1.00	20.8	23.6	13.6
Difference.....	3.50	3.92	2.67	-4.0	15.8	3.0
Fisher t.....	2.003	3.021	2.243	1.207	1.319	0.816
Probability difference due to chance .....	.05 to .10	less than .01	.02 to .05	.20 to .30	.02	.40 to .50

* This and the following tables of this nature should be read as follows: On trial 11 in comparing the difference in the error scores between the means of Group 3a and Group 3b, the number of cases in both groups being 22, Fisher t function is 2.003, which indicates the chances are between five and ten out of 100 that the difference between the means is due to a chance factor.

For details of statistical technique used and talks of "t" and "q" see Fisher, R. A., "Statistical Methods for Research Workers" (ed. 3, Edinburgh, Oliver and Boyd, 1930).

inspection of tables 2 and 3 indicates that there was a statistically significant difference on day 12 in both time and excess-distance scores. Qualitatively it was observed that the animals hesitated

and seemed to eat less "confidently" but this tendency seemed short-lived. The food seems to be undoubtedly the focal stimulus. That is to say, although the rats could discriminate the box as a different box, so long as it was "a box-containing-food" there was no *continued* disturbance in maze performance.

3. *Results when food was removed.*—When the food was removed there was an increase for both groups (Groups 1 and 3) in excess distance and a corresponding increase in time. (See figs. 1 and 2 and tables 1 and 4.) This rise seems to be characteristic and has been observed by all investigators (see Literature Cited p. 82).

It should be noticed that Group 1, the group run and fed every 24 hours, rose more in both excess distance and time scores than did Group 3, the 48-hour group. An inspection of table 4 indicates that there was a significant difference between Group 3 and the control group, but it seems doubtful that the difference between the two experimental groups either in the time or the excess-distance scores can be considered significant.

4. *Results when rats were "double hungry."*—When both Groups 1 and 3 had reached a relatively stable level of performance after the food reward was removed, an added 24-hour period without food was introduced between trials for each group. This was after the twenty third trial for Group 1 and after the nineteenth trial for Group 3. (See table 1.) An inspection of table 4 indicates that there is a statistically reliable difference between Groups 1 and 3 in the excess distance scores and probably in the time scores, although this last is not as reliable. This increased time in running about in the maze for the rats of Group 3 continued on trials 21 and 22 even though they were no longer "double hungry." It also appears that there is a statistically reliable difference in the excess distance scores between the two experimental groups, Groups 1 and 3, on the trial when they were both "double hungry," the 24 hour group showing the greatest rise in the excess-distance scores.

On the twenty sixth trial, when the rats of Group 1 were put into the maze when not hungry, they showed a large increase in time. (See present series, 4 203-214.)

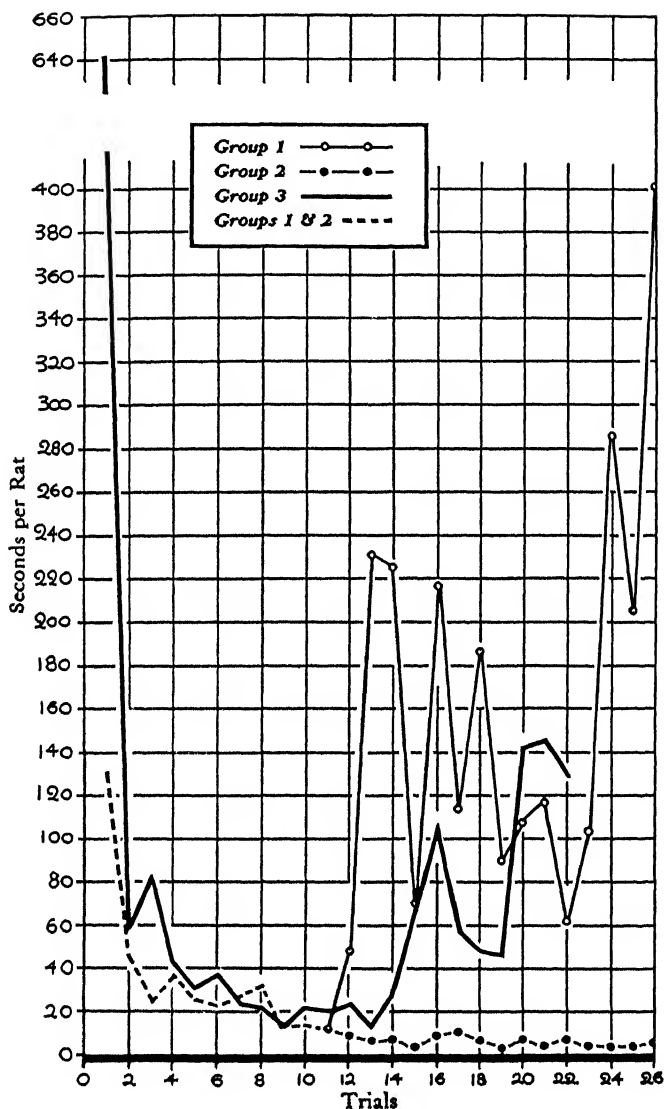


Fig. 2. Average Time in Seconds per Rat

TABLE 4

COMPARISON BETWEEN MEANS OF GROUPS 1 AND 3; AND GROUPS 2 AND 3, WHEN FOOD WAS REMOVED FROM GROUPS 1 AND 3

		Excess distance			Time		
Group 1 (n=12) and Group 3 (n=24)	Group 1 trials.....	12	13	24	12	13	24
	Group 3 trials.....	15	16	20	15	16	20
	Group 1 Mean.....	5.91	14.91	22.5	48.48	231.0	286.6
	Group 3 Mean.....	8.71	7.88	6.23	64.8	105.7	142.1
	Difference.....	-2.80	7.03	16.27	-16.32	125.3	144.5
	Fisher t.....	.833	1.057	2.242	.689	0.414	.964
	Probability difference owing to chance.....	.40 to .50	.20 to .30	.02 to .05	.40 to .50	.60 to .70	.30 to .40
Group 2 (n=14) and Group 3 (n=24)	Group 2 trials.....	12	13	24	12	13	24
	Group 3 trials.....	15	16	20	15	16	20
	Group 2 Mean.....	.57	2.92	.85	4.55	9.77	4.51
	Group 3 Mean.....	8.71	7.88	6.23	64.8	105.7	142.1
	Difference.....	-8.14	-4.96	-5.38	-60.25	-95.93	-137.59
	Fisher t.....	3.996	2.505	2.372	3.155	2.573	1.329
	Probability difference owing to chance.....	less than .01	slightly over .01	.01 to .02	less than .01	.01	.10 to .20

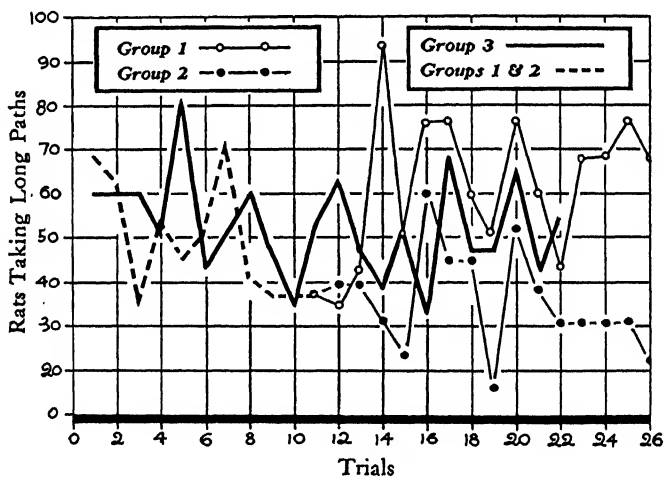


Fig. 3. Percentage of Rats Taking Long Paths

SUMMARY AND CONCLUSIONS

1. When the reward was removed from a group of rats run every 48 hours in a square maze there was the same sort of a significant rise (although not so great) in excess distance and in time as was found previously with rats run every 24 hours.

2. When hunger conditions were increased the 24-hour group showed larger increases in distance run and in time consumed than did the 48-hour group.

3. A different food box with food in it was introduced (with the 48-hour group) in the early part of the experiment before the food reward was removed. This produced a temporarily significant change in the rats' performance, after which the performance tended to resume its previous course.

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THE EFFECT OF REMOVAL OF REWARD ON THE MAZE PERFORMANCE OF RATS. III

BY
ROBERT HALL BRUCE

FOOD PUT BEHIND WIRE MESH

(GROUP 4)

In this third study the effect not of complete removal but of placing the food reward behind a wire mesh is investigated. Group 4, composed of 26 albino rats, like Group 1 (see p. 66), was run and fed once every day until day 11. Instead, however, of entirely removing the food from the box, as was done with Group 1, the food was placed behind wire mesh. This enabled the rat to see and smell the food, but prevented his eating it. The problem was to see the effect upon maze performance of having the food reward present but uneatable, thus allowing the organism to make the pre-current responses, but barring the consummatory response of eating.

All rats of Group 4 were of approximately the same age, three months, and were of the general laboratory stock. Until the eleventh day they, like Group 1, were fed in the food box at the end of the daily run, and when the food reward was removed they, like Group 1, were fed six hours later in their cages.

The same maze and general technique were used as before. Finally, the rats of Group 4 were also given a "double hungry" day—an added 24-hour period without food—before the twenty-fourth trial.

Fisher "t" functions, to indicate the reliability of the differences between the means of the three groups for both the time and the excess-distance scores, were computed for trials 10, 11, 12, 13, 14, 15, and 24.

RELIABILITY

The reliability of the maze under reward conditions and two types of non-reward conditions, as measured by the correlation of odd versus even trials, was computed for Group 4 of this study and for Groups 1 and 2 of the previous studies. This was done to see how this square type of maze would compare with the multiple T type of maze on which reliabilities were computed by Tolman and Honzik (1930).

RESULTS

1. *When the food was removed.*—When the food was removed from Groups 1 and 4 there was a significant rise in both the time and the excess-distance scores. (See figs. 1, 2, and 3, and tables 1,

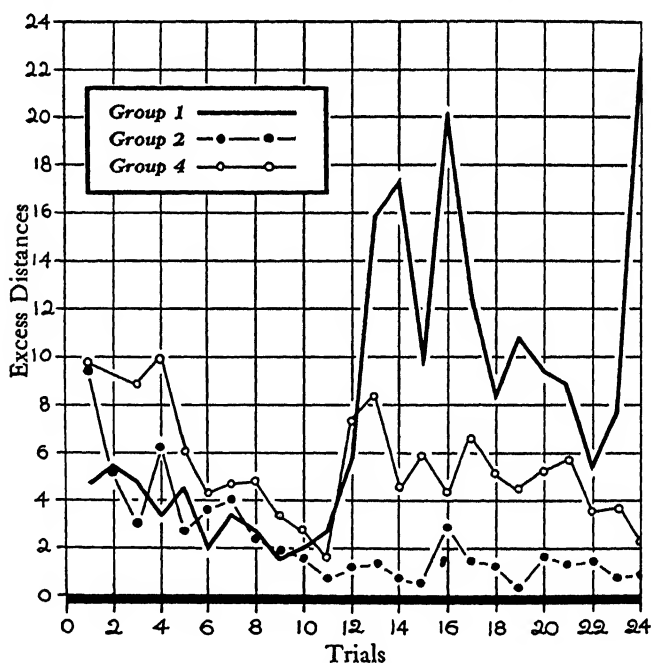


Fig. 1. Excess Distance per Rat

2, and 3.) An inspection of table 1 and figure 1 indicates that the rats of Group 4, which had the food present behind wire mesh, did not run around in the maze so much as Group 1. Evidently the fact that the food was present even though uneatable served to modify significantly the performance of the rats. Quantitatively

TABLE 1

Day	Average excess distance per rat			Average time in seconds per rat			Percentage of rats taking long paths		
	Group 1	Group 2	Group 4	Group 1	Group 2	Group 4	Group 1	Group 2	Group 4
1.....	4 30	9 35	9 85	93 13	167 84	357 42	38.5	78.7	46.2
2.....	5 53	4 78	9 31	49 27	43 73	216 54	61.5	42.9	42.3
3.....	4 38	3 0	8 96	29 24	21 34	90 46	7 5	42.9	38.5
4.....	3 33	6 07	9 96	35 41	39 10	150 46	33 3	53.5	46.2
5.....	4 33	2 85	6 0	36 91	15 0	131 15	41 6	29.0	15.4
6.....	2 0	3 57	4 12	20 58	27 0	42 23	41 6	42 9	42.3
7.....	3 33	4 0	4 09	19 5	33 77	36 81	66 6	57.1	38.5
8.....	2 66	2 57	4 88	20 04	45 04	33 15	33 3	29.0	34.6
9.....	1 58	1 0	3 35	9 06	22 51	24 77	33 3	21 3	34.6
10.....	2 0	1 57	2 81	15 73	13 55	20 15	25 0	29.0	26.9
11.....	2 66	.85	1 65	14 85	9 91	15 58	33.3	21 3	19 2
Food removed (Groups 1 and 4)									
12.....	5 91	1 14	7 27	48 48	9 31	91 46	25 0	29.0	42 3
13.....	14 91	1 42	8 27	231 0	7 07	91 62	33 3	29.0	34 6
14.....	17 16	.85	4 58	225 25	7 42	49 96	83 4	21.3	46 2
15.....	9 91	.57	5 96	69 54	4 55	61 85	41 6	13.8	19 2
16.....	18 91	2 92	4 23	210 96	9 77	41 62	66 6	50.0	38 5
17.....	12 34	1 42	6 65	114 48	10 88	80 12	66 6	35.5	38 5
18.....	8 41	1 14	5 08	180 16	7 31	45 5	80 0	35.5	50 0
19.....	10 75	.28	4 50	90 93	3 95	57 42	41 6	6 6	30 8
20.....	9 41	1 85	5 15	108 9	7 48	90 85	66 6	42 9	42.3
21.....	8 91	1 42	5 62	117 13	5 31	55 73	50 0	29.0	46 2
22.....	5 33	1 57	3 58	63 03	7 12	32 65	33 3	21 3	34 6
23.....	7 66	.85	3 69	104 73	5 41	45 5	58 4	21 3	26 9
24.....	22 5*	.85	2 15*	286 6*	4 51	22 62*	58 4*	21.3	38 5*

* Double hungry.

this is shown most clearly on day 14 when both the time and excess-distance scores show a significant difference between the means of Groups 1 and 4. (See tables 2 and 3.) Qualitative observations bear out this generalization, for the rats of Group 4 were observed trying to reach the food in the box by stretching their fore limbs through the mesh, flattening themselves against the wire, and generally behaving as though the food continued to be a focal stimulus,

although uneatable. That this behavior was persevered in is shown by an inspection of table 1, which indicates that never after day 12 did the rats of Group 4 exhibit so much excess distance per rat as did the rats of Group 1. This tendency is also shown by the fact

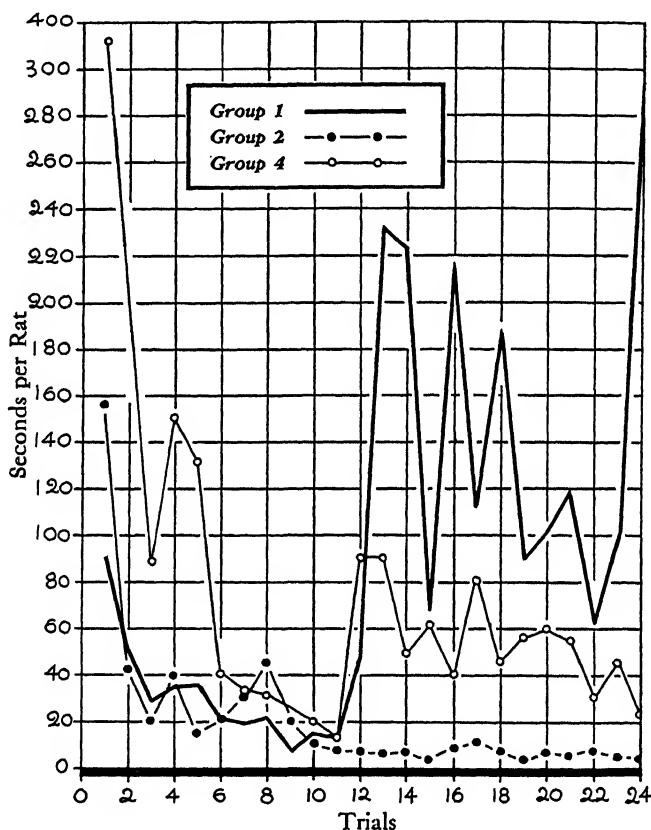


Fig. 2. Average Time in Seconds per Rat

that the rats of Group 1 took the long path to the food box more consistently than did the rats of Group 4. (See fig. 3.) It would appear that the pre-current responses involved in seeing and smelling, are enough of a surrogate for the consummatory response of eating to keep behavior oriented toward the food box.

2. *Results when the rats were "double-hungry."*—That the above discussed factors are the determinants of performance is made even more evident by an inspection of the results when the rats of Groups 1 and 4 were made "double-hungry." This was accomplished by adding 24 hours without feeding between the trials, thus having a total time of 42 hours since the rats had been fed. When this was done the rats of Group 1, with the food entirely removed, showed an *increase* in distance run about in the maze,

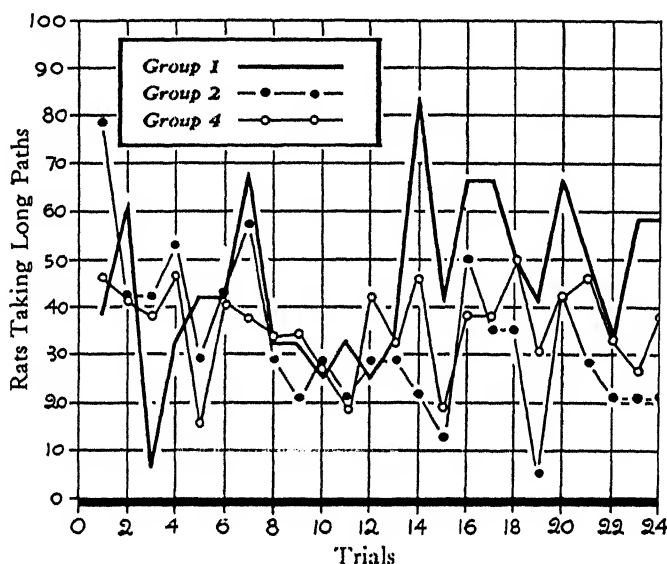


Fig. 3. Percentage of Rats Taking Long Paths

averaging 22.5 units of excess distance per rat, while the rats of Group 4, with the food present but uneatable, *dropped* to a level of 2.15 units of excess distance per rat. That there is a significant difference between the means of the two groups in both the time and the excess-distance scores on trial 24, the "double-hungry" trial, is evidenced by an inspection of tables 2 and 3. It would seem that, while the rats of Group 1, with the food entirely removed reacted to the box as possessing the specific character "non-reward," the rats of Group 4, with the food present but uneatable, persevered in reacting to the box as a "reward" object, therefore keeping their behavior oriented toward this object.

TABLE 2

THE RELIABILITY OF THE DIFFERENCES BETWEEN MEANS OF THE GROUPS IN THE EXCESS-DISTANCE SCORES

		Daily trials						
		10	11	12	13	14	15	24
Group 1 (n=12) and Group 2 (n=14)	Group 1.....	2.0	2.66	5.91	14.91	17.16	9.91	22.5
	Group 2.....	1.57	.85	1.14	1.42	.85	.57	.85
	Difference.....	.43	1.81	4.77	13.49	16.31	9.34	21.65
	Fisher t.....	.333	2.002	1.327	1.668	4.603	2.971	2.418
	Probability difference due to chance.....	.70 to .80	.05 to .10	.10 to .20	.10 to .20	less than .01	less than .01	.02 to .05
Group 1 (n=12) and Group 4 (n=24)	Group 1.....	2.0	2.66	5.91	14.91	17.16	9.91	22.5
	Group 4.....	2.81	1.65	7.27	8.27	4.58	5.96	2.15
	Difference.....	-.81	1.01	-1.36	6.64	12.58	3.95	20.35
	Fisher t.....	.562	1.197	.314	.894	4.550	1.750	3.114
	Probability difference due to chance.....	.50 to .60	.20 to .30	.70 to .80	.30 to .40	less than .01	.05 to .01	less than .01
Group 2 (n=14) and Group 4 (n=24)	Group 2.....	1.57	.85	1.14	1.42	.85	.57	.85
	Group 4.....	2.81	1.65	7.27	8.27	4.58	5.96	2.15
	Difference.....	-1.24	-0.80	-6.13	-6.85	-3.73	-5.39	-1.30
	Fisher t.....	.954	.899	1.909	1.595	2.288	1.326	1.470
	Probability difference due to chance.....	.30 to .40	.30 to .40	.05 to .10	.10 to .20	.02 to .05	.10 to .20	.10 to .20

TABLE 3

THE RELIABILITY OF THE DIFFERENCES BETWEEN MEANS OF THE GROUPS IN THE TIME SCORES

		Daily trials						
		10	11	12	13	14	15	24
Group 1 (n=12) and Group 2 (n=14)	Group 1.....	15.73	14.85	48.48	231.0	225.25	69.54	286.6
	Group 2.....	13.55	9.91	9.31	7.07	7.42	4.55	4.51
	Difference.....	2.18	4.94	39.17	223.93	217.83	64.99	282.09
	Fisher t.....	.199	.751	2.114	1.811	2.632	2.425	2.143
	Probability difference due to chance.....	.80 to .90	.40 to .50	.02 to .05	.05 to .10	.01 to .02	.02 to .05	.02 to .05
Group 1 (n=12) and Group 4 (n=24)	Group 1.....	15.73	14.85	48.48	231.0	225.25	69.54	286.6
	Group 4.....	20.15	15.58	91.46	91.62	49.96	61.85	22.62
	Difference.....	-4.42	-0.73	-42.98	139.38	175.29	7.69	263.98
	Fisher t.....	.763	.132	.726	.579	2.790	1.185	2.764
	Probability difference due to chance.....	.40 to .50	.80 to .90	.40 to .50	.50 to .60	less than .01	.80 to .90	less than .01
Group 2 (n=14) and Group 4 (n=24)	Group 2.....	13.55	9.91	9.31	7.07	7.42	4.55	4.51
	Group 4.....	20.15	15.58	91.46	91.62	49.96	61.85	22.62
	Difference.....	-6.60	-5.67	-82.15	-84.55	-42.54	-57.30	-18.11
	Fisher t.....	1.025	1.222	1.548	1.769	2.195	1.467	4.254
	Probability difference due to chance.....	.30 to .40	.20 to .30	.10 to .20	.05 to .10	.02 to .05	.10 to .20	less than .01

RELIABILITY COEFFICIENTS OF THE MAZE FOR REWARD AND NON-REWARD PERIODS

In order to ascertain the reliability of this type of square maze, even with the small number of cases employed, the reliability coefficients based on odd-day versus even-day scores for both the excess-distance and the time scores were computed. These are given in table 4.

TABLE 4

RELIABILITY COEFFICIENTS BASED UPON EVEN-DAY VERSUS ODD-DAY SCORES IN
EXCESS DISTANCE AND IN TIME

Group	Reliability coefficients for excess distance scores	Reliability coefficients for time scores
Group 1, days 2-11 (hungry - food present).....	— .295	.330
Group 1, days 12-23 (hungry - food entirely re- moved).....	.449	.734
Group 2, days 2-23 (hungry - food present).....	.367	.702
Group 4, days 2-11 (hungry - food present).....	.361	.609
Group 4, days 12-23 (hungry - food present but uneatable).....	.859	.640

It will be noticed that they are much lower than those reliability coefficients previously reported for a 14-unit multiple T type maze by Tolman and Honzik. The highest reliability is found in Group 4, days 12-23, where the rats are hungry, not rewarded, but the food present in the box. The time scores seem more consistently reliable than the excess-distance scores.

SUMMARY AND CONCLUSIONS

1. When the food reward was removed from a group of albino rats by placing it behind a wire mesh, there was a significant rise in both the time and the excess-distance scores. There is a statistically significant difference between the rats of this group and a

group from which the food had been entirely removed, the rats of the former group doing less running about in the maze and consuming less time. It would seem that the pre-current responses involved in seeing and smelling the food are enough of a surrogate for the consummatory response of eating, to keep the behavior to a greater degree oriented toward the food box.

2. When the rats with the food entirely removed from the box were made "double-hungry" their performance *increased* to a level of 22.5 units of excess distance per rat, while the performance of the rats with the food present but uneatable *dropped* to a level of 2.15 units of excess distance per rat. It would seem that while the rats with the food entirely removed reacted to the box as possessing the specific character "non-reward," the rats with the food present although uneatable, persevered in reacting to the box as a "reward" object, thus keeping their behavior oriented toward this object.

3. Reliability coefficients for the maze were computed and were generally lower for this square type of maze than for a multiple T type of maze. The time scores showed more consistent reliabilities than did the excess-distance scores.

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“SPECIFIC” VS. “GENERAL” ORIENTATION FACTORS IN MAZE RUNNING

BY

E. L. BALLACHEY AND I. KRECHEVSKY

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“SPECIFIC” VS. “GENERAL” ORIENTATION FACTORS IN MAZE RUNNING

BY

E. L. BALLACHEY AND I. KRECHEVSKY

In recent analyses of maze running by the white rat, attempts have been made to ascertain those factors which determine the animal's behavior at each choice-point. This is a recognition of the frequently observed fact that the different culs-de-sac of any given maze vary in degree of difficulty and that the maze cannot be considered a homogeneous instrument. This differential difficulty of blinds has suggested the possibility of a more precise analysis of animal learning than is possible by the mere consideration of gross error scores.

Studies bearing on this question by Tolman and Honzik (1930), Yoshioka (1930*a*), Dashiell (1930), and Dashiell and Bayroff (1931), all advance the possibility of the existence of *general* factors as determiners of the rat's behavior at any given choice-point. Thus Tolman (1932; citing his own and other evidence) suggests the concept of “spatial-direction-of-the-goal expectation” to account for the differential difficulty of blinds in a maze. According to this concept the rat builds up some *general* orientation toward the direction of food and, as a result, would be prone to enter those blinds which point in the same general direction as the food box more frequently than those blinds which point away from the food.

Dashiell seems to advocate a like treatment of his own data, and in his monograph (1930) concludes that he has demonstrated that

the rat when running a maze early shows the influence of some direction-orienting tendency that operates independently of specific stimuli to particular local movements . . . this . . . appears as a tendency to make errors in those blind alleys that happened to open up in the general direction of the food box more than in those opening in the reverse direction.

Such explanations are applicable only to rats which have had sufficient training to learn the spatial features of the maze and the relation of the goal to the various blinds.

Dashiell and Bayroff (1931) have attempted some analytical studies of the naïve rat's behavior in a maze. They were interested in those factors which determine the initial choices of the rat when placed in a maze for the first time.

These experimenters employed two forms of the multiple U-type maze. The two mazes were equal in all respects except that the "C-type" maze "involved choice-turns in the true path always in one *constant* direction . . . while the other ["A-type"] involved choice-turns in the true path alternately right and left."

The C-type maze was found to be strikingly easier for the rats than the A-type. Emphasizing the fact that the C-type maze "is not only distinctly easier to master . . . it is distinctly easier to run on the very first trial, i.e., before the animals have had any experience at all with the food-box-in-position-with-relation-to-maze," the authors, after a consideration of various possible explanations, conclude that "it seems likely that the factor most responsible is a forward-going tendency in animal locomotion." Such an explanation, it is seen, extends the concept of generalized directive forces and includes such factors among those operative from the moment the animal is first introduced into the maze.

It is necessary to consider in some detail precisely what Dashiell and Bayroff mean by the concept of a "forward-going" tendency. An examination of the apparatus and method of analysis used by Dashiell and Bayroff will aid us in defining this concept. In order to test the adequacy of their explanation of the results obtained from the C-type and A-type mazes, Dashiell and Bayroff ran 181 rats (broken up into two general groups of "motivated" and "unmotivated" rats) in a simple maze consisting of a straightaway, an elbow and a T-choice with one alley running forward and one backward (fig. 1).¹

¹ It should be pointed out that the C-type maze consisted of several such units, with the true paths always leading off from the forward-pointing alley (alley *D* in fig. 1) and the backward pointing alley (*E*) being always the cul-de-sac.

They found a tendency for the rats to choose the "forward-going alley (alley *D*, fig. 1). The authors then suggest that

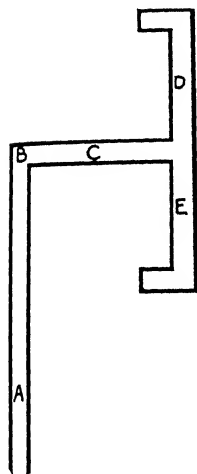


Fig. 1

one way of describing this tendency in particularized and explicit terms would be to say that when an animal is forced 90° out of its line of movement in a maze by an elbow in the pathway, when it is next offered a choice between a turn reversing the first one and a turn repeating it, it is more likely to choose the former.

It should be emphasized that Dashiell and Bayroff thus consider the elbow as an *obstacle* in the path, which temporarily diverts the animal from his "forward-going" line of locomotion and which is compensated for when the *obstacle* is removed. The interpretation of Dashiell and Bayroff would then describe the animal's behavior at bifurcation *D-E* as a function of the direction of movement in alley *A*.

Rather than regard the elbow *B* as a passive obstruction in the line of movement for which the animal compensates by a return to the first direction of locomotion, the present authors suggest that the turning of the elbow *B* is the *actual determiner* of the turn into *D*, and that the general direction of movement in alley *A* is not a cause of the animal's behavior at choice-point *D-E*, in other words, *the fact that both A and D point in the same direction is irrelevant*. Such a contention would explain this *D-E* behavior, not by appealing to the presence of some "general" direction-force at work, but by describing this phenomenon as a specific response to the unique, purely local character of the elbow *B*.

This alternative description was suggested to the authors by a consideration of the concept of "centrifugal swing" advanced by Schneirla (1929). In his analysis of maze running by ants, Schneirla observed that

an ant in the maze for the first time does not behave in a purely "random" manner. . . . Rather, within limits, the observer can accurately predict the behavior of the animal, provided the significance of certain pattern features

of the maze is known to him. The spatial arrangement of the maze alleys . . . is important for the influence we shall term *centrifugal swing* . . . In general, it [centrifugal swing] depends upon the physical fact that in passing around a corner with reasonable speed, the animal must run near the outside walls of the turns . . . while the ant is under the influence of this centrifugal swing, movements compatible with it . . . will be easily made.

Referring again to figure 1, it is seen that according to the concept of "centrifugal swing" the animal would, after being forced around the 90° turn at *B*, be "thrown" toward the outside wall of *C* and therefore approach the bifurcation *D-E* in closer proximity to alley *D* than to alley *E*. It needs to be emphasized that the entrance into *D* is a function of the elbow *B* and not a consequence of the general direction of the animal's locomotion in alley *A*.

Either of these two opposed explanations would predict the animal's entrance into *D*, since alley *D* happens to point in the same direction as alley *A*. The data from Dashiell and Bayroff are therefore ambiguous in respect to the relative validity of the two explanations. To obtain critical evidence upon the merits of these two hypotheses it is necessary to set up a situation such that, if a "forward-going" tendency were the determiner of the animal's choice at the bifurcation, the animal would be forced into one alley; but were "centrifugal swing" or any other purely local factor the determiner of the rat's choice, it would be forced into the opposite alley.² The purpose of the present study was to attempt to set up such a situation and to analyze the resulting data in the light of the above discussion.

² In adopting the term "centrifugal swing" we do not necessarily imply that the descriptive connotation of this term is adequate to describe the actual sequence of movements in the elbow. From general observation of the animals' behavior we *would* be inclined to think so but pending more careful study (cinematographic analysis) we would suspend final judgment. What we do wish to imply by the term is that, whatever be the actual sequence of movements in the elbow, it is the specific elbow-situation, and not a more general factor, which determines the animals' behavior at the subsequent bifurcation.

The animals received no food in their nest cages. After this period of 21 days the rats were run through the apparatus shown in figure 2, four trials a day for five days. On alternate trials the elbows (*B*, *C*, *D*, and *E*) were shifted to the opposite side of the straight-

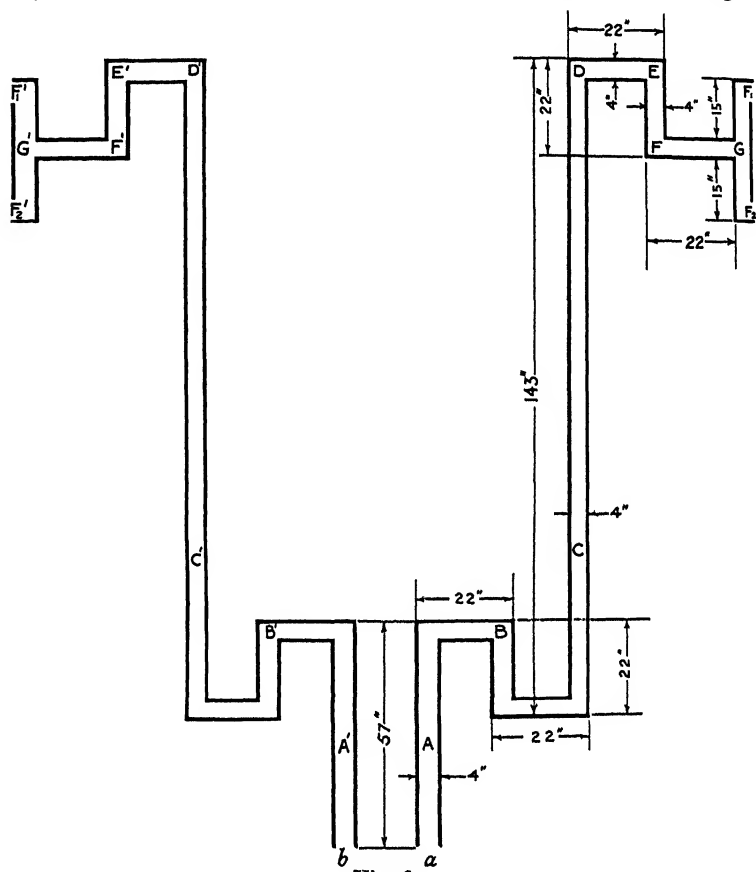


Fig. 3.

away. Thus, if the rats were run on the first trial with the elbows in position *B C D E*, they would be given the second run with the elbows in position *B' C' D' E'*.

The day following the completion of the preliminary training the test runs were made in the apparatus shown in figure 3. The alleyways were of unpainted redwood, 4 inches wide by 6 inches

deep. They were covered with a fine wire mesh. The bends consisted of elbows of identical construction, which were interchanged to prevent tracking.

The rat was introduced into the apparatus at *A*. At *G* he was allowed to continue to either F_1 or F_2 where he received a pellet of food. In order to determine and control the effect of "positional preferences" on the behavior of the rat at the choice-point, the animals were divided equally in two groups: Group I was given five trials in the apparatus as shown in figure 3*a*, Group II was given five trials in the mirror image of this set-up (fig. 3*b*). On the second day Group I was transferred to the apparatus in position *b*; Group II, to that in position *a*.

It will be seen from the maze diagrams that an entrance into F_1 (F_1') would be in accordance with the concept of a "forward-going" tendency and an entrance into F_2 (F_2'), with the concept of "centrifugal swing."

The long preliminary training period was instituted in order to increase the probability that the rats would make a "forward-going" choice at *G* and *G'* if such a tendency were a factor in the choice-point behavior of the rat. It may be objected that forcing the rat to turn back on his initial path at point *E* (*E'*) may disrupt the original "forward going" tendency, and thus decrease the probability of a "forward going" choice at *G*. To meet this objection each animal was given, it should be remembered, 20 trials in the apparatus shown in figure 2. There the rat was forced, after running through section *B C D E*, to continue in the original "forward-going" direction to *F* where he received food. Furthermore, in the test run itself, the animal, after traversing section *B* (fig. 3), was forced to resume his original direction of locomotion in alley *C*.

DATA AND DISCUSSION

Table 1 presents the cumulative scores (per trial) expressed as percentages of the cumulated total for both groups of animals. In the third row of the table are presented the standard errors of the percentages for each trial.⁴ The fourth row presents that percentage which should have obtained for either the "centrifugal

TABLE 1
CUMULATIVE "CENTRIFUGAL SWING" AND "FORWARD-GOING"
SCORES (PERCENTAGE)

Trial	1	2	3	4	5	6	7	8	9	10
Centrifugal swing..	54.17	50.25	58.33	60.42	61.67	61.81	59.52	59.38	60.65	59.58
Forward-going.....	45.83	49.75	41.67	39.58	38.33	38.19	40.48	40.62	39.35	40.42
σ	11.9	7.2	5.9	5.1	4.5	4.2	3.8	3.6	3.4	3.2
50%+3 σ	85.7	71.6	67.7	65.3	63.5	62.6	61.4	60.8	60.2	59.6

swing" or "forward-going" score, in order to assure us that the percentage was significantly different from that which might have occurred by chance. These percentages (i.e., the scores in the fourth row) were obtained by adding 3 σ to 50 per cent.

It will be seen from the total score (i.e., cumulative score, tenth trial) that *the animals were making a significantly greater number of "centrifugal swing" choices than chance alone would permit.* These scores represent composite scores with any possible influence of "positional preferences" controlled and can only be interpreted to mean that of any of the following factors: "positional preference," "forward-going" tendency, or "centrifugal swing," the last named was the prepotent factor operative in determining the behavior of the *group* at choice-point *G*.

⁴ The common formula $\sigma = \sqrt{\frac{pq}{N}}$ was used to compute these standard errors. *N*, of course, increased by steps of 24 each trial, *p* and *q* remaining constant, i.e., .5 and .5.

TABLE 2
INDIVIDUAL RECORDS, GROUP I

Rat	Position A		Position B		Total Centrifugal swing	Total Forward-going	Position Response	
	Centrifugal swing	Forward-going	Centrifugal swing	Forward-going			Right	Left
1	3	2	4	1	7	3	4	6
2	4	1	5	0	9	1	4	6
3	2	3	3	2	5	5	4	6
4	5	0	2	3	7	3	8	2
5	3	2	3	2	6	4	5	5
6	3	2	3	2	6	4	5	5
7	4	1	1	4	5	5	8	2
8	3	2	2	3	5	5	6	4
9	5	0	0	5	5	5	10	0
10	5	0	3	2	8	2	7	3
11	5	0	4	1	9	1	6	4
12	5	0	5	0	10	0	5	5
Total	47	13	35	25	82	38	72	48

TABLE 3
INDIVIDUAL RECORDS, GROUP II

Rat	Position A		Position B		Total Centrifugal swing	Total Forward-going	Position Response	
	Centrifugal swing	Forward-going	Centrifugal swing	Forward-going			Right	Left
13	5	0	0	5	5	5	10	0
14	5	0	3	2	8	2	7	3
15	5	0	2	3	7	3	8	2
16	0	5	3	2	3	7	2	8
17	2	3	4	1	6	4	3	7
18	1	4	1	4	2	8	5	5
19	1	4	3	2	4	6	3	7
20	4	1	1	4	5	5	8	2
21	0	5	5	0	5	5	0	10
22	5	0	0	5	5	5	10	0
23	1	4	4	1	5	5	2	8
24	5	0	1	4	6	4	9	1
Total	34	26	27	33	61	59	67	53

Turning now to a consideration of each one of these possible factors, we shall attempt to ascertain the importance of these variables by an analysis of individual scores.

1. *Positional Preferences*.—Yoshioka (1928) suggests the possibility that a "positional preference" on the part of the rat may be a determining factor influencing the animal's behavior at any given choice-point when first introduced in a maze. In later articles Yoshioka (1930*b*) and Gengerelli (1930) have shown the actual existence of "positional preferences" in untrained rats. It is obvious, therefore, that some such factor may have been operative at choice-point G (*G'*) in the present experiment. If such were the case for any one rat, the animal would have divided his choice equally between "centrifugal swing" responses and "forward-going" responses, since in position 3*a* (fig. 3) a "turn to the right" would have been scored as a "centrifugal swing" choice and a "turn to the left" as a "forward-going" choice; whereas in position 3*b* just the reverse would have obtained. Since each animal was run in both positions the "forward-going" and "centrifugal swing" scores should therefore have been approximately equal.

Tables 2 and 3 present the data for the individual animals in both positions. Total "centrifugal swing" scores, "forward-going" scores, and "positional" scores are given. Defining arbitrarily a "positional" animal as one which makes at least eight out of the ten choices to the right (or to the left), we see that 11 of the 24 are "positional" rats. Eight favored the right position; three, the left.

Such an arbitrary definition leaves out of consideration those animals which showed a somewhat lesser tendency to prefer one side to the other. Nine rats showed such a preference, at least to the extent of 6 out of 10. Considering these nine animals as a group we have presented in table 4 the effect of "centrifugal swing" on the *apparent* "positional preference." The data for this table were obtained by first determining the position preferred by each animal, then, under the "C.S. + " rubric, indicating the

number of choices in keeping with such a tendency when this tendency was also a "centrifugal swing" turn; again, under the rubric "C.S. -" the number of such choices opposed to a "centrifugal swing" turn. Thus we can determine the effect of "centrifugal swing" upon a relatively slight "positional preference." From these data we see that of the 58 "positional" responses, 37 were made when "centrifugal swing" did not oppose such a turn and only 21 when "centrifugal swing" opposed the turn to the preferred side. The probability of these 37 choices occurring with "centrifugal swing" responses by *chance* alone is only 1.74 in a hundred.⁵

Objection may be raised to such a statistical treatment on the ground that in considering the 37 choices as a lump amount we may be giving undue weight to the performance of two or three animals which showed that tendency, whereas what we should be interested in is whether or not the *average* positional animal showed the same thing. To answer this objection we have determined the reliability of the difference between the *means* of the two groups ("C.S. +" and "C.S. -") by the use of Fisher's *t*.⁶ The obtained *t* is 3.90928, which can be interpreted to mean that the probability of the difference between the obtained means occurring by chance is *less than one* in a hundred.

It follows then, that even *in those rats which displayed a slight tendency to respond on the basis of "positional preferences," "centrifugal swing" operated in some degree.*

⁵ This probability was obtained by first determining the sigma from the formula $\sigma = \sqrt{pqN}$ when $p = .50$; $q = .50$ and $N = 58$ (i.e., $37 + 21$). Doing this, sigma is found to be 3.80. Thirty seven is then 2.105 σ 's away from the score expected by chance, 29, or 50 per cent of 58.

$$t = \frac{1}{N} \left(\frac{1}{n_1 + 1} + \frac{1}{n_2 + 1} \right) - \frac{(n_1 + n_2 + 2)}{(n_1 + 1)(n_2 + 1)(n_1 + n_2)} \left(\sum x - (x^2) + \sum (x^2) + (x^3) \right) \\ t = \frac{x - x^2}{N} \sqrt{\frac{(n_1 + 1)(n_2 + 1)}{n_1 + n_2 + 2}} \\ n = n_1 + n_2$$

This method of analysis is one which is appropriate for our data inasmuch as the number of cases used was less than 30. For the meaning of these statistics see Fisher (1928).

In this analysis of the effect of position we have now considered all but four animals. These four animals, as can be seen from tables 2 and 3, divided their responses, as far as position is concerned, exactly evenly—five to the right and five to the left.

2. *Forward-going tendency.*—From our discussion of the entire group result (p. 90) it was seen that, so far as the group was concerned, a statistically significant number of its choices was opposed to the “forward-going” concept. Of the total of 240 choices but 40.42 per cent were “forward-going” turns. This is *significantly less* than 50 per cent, whereas if a “forward-going” tendency were at work we should have obtained a percentage *significantly greater* than 50 per cent.

An examination of the individual records substantiates the fact of the absence of any “forward-going” tendency of any importance.

If we apply the same criterion here that was applied in discussing the “positional” rats we find that *only one rat of the 24 showed a consistent “forward-going” tendency.* Rat 18 (table 3) chose a “forward-going” turn eight times in the ten trials, with his position responses divided equally between right and left turns. Besides this one animal only two other rats showed even the slightest preference for a “forward-going” response, rats 19 and 16. Rat 19 favored the “forward-going” turn to the extent of 6 to 4, and rat 16, to the extent of 7 to 3. These differences in favor of the “forward-going” choices are so slight that they can hardly be accepted as evidence indicating any real effect of such a tendency, and of further significance is the fact that *these two animals could have been categorized as left-position animals with even more assurance, for rat 19 favored the left choice to the extent of 7 to 3 and rat 16 to the extent of 8 to 2.*

The only conclusion possible in the light of these facts is that our data show an almost insignificant effect of any “forward-going” tendency.

3. *Centrifugal swing.*—The gross group scores have already been discussed (see p. 90). By experimentally controlling any

effect of "positional preference," it was shown that, for the entire group, "centrifugal swing" was the most important determiner of the animal's choices.

Examination of the individual scores (tables 2 and 3) reveals that five rats met our criterion of 8-2 and may thus be classified as "centrifugal swing" rats. It is further to be noted that this classification of these five animals is the most valid, since none of the five showed greater preference (i.e., 8-2) for "positional" responses.

Up to this point we have definitely classified 17 animals (table 5) as showing either a "positional preference," a "forward-going" response, or a "centrifugal swing" response. This leaves seven animals which showed no definite preference. Of these seven animals, three (Nos. 1, 5, 6) made a greater number of "centrifugal swing" turns than of either positional or "forward-going" turns.

It should be pointed out that the concept of "centrifugal swing" as a factor influencing the choice-point behavior of a rat is more important in the determination of the locus and frequency of errors in a maze containing elbows than would appear from our data. From unpublished data it appears that it is possible to vary the difficulty of a maze and the difficulty of the various blinds in the maze by so arranging the sequence of turns that "centrifugal swing" would force the rats into either the blinds or the true path. In the construction of a maze, it is an important factor to be considered.

Such determiners of error scores as food-pointingness (Tolman, Dashiell), general direction orientation (Yoshioka, Dashiell), "forward-going" tendency (Dashiell and Bayroff), and the like have been deduced from an analysis of the difficulty of blinds. It is suggested in the light of the present experiment that the influence of such a specific, local factor as "centrifugal swing" must be considered before the distribution of error scores is attributed solely to any such general factors.

TABLE 4

EFFECT OF "CENTRIFUGAL SWING" ON "POSITIONAL PREFERENCES"

Rat	Centrifugal swing+	Centrifugal swing-
14	5	2
17	4	3
19	3	4
1	4	2
2	5	1
3	3	3
8	3	3
10	5	2
11	5	1
Total	37	21

TABLE 5

CLASSIFICATION OF INDIVIDUALS MEETING NORM

Rat	Centrifugal swing	Forward-going	Positional
2	x		
4			x
7			x
9			x
10	x		
11	x		
12	x		
13			x
14	x		
15			x
16			x
18		x	
20			x
21			x
22			x
23			x
24			x
Total	5	1	11

SUMMARY

Twenty-four white rats were run through a situation designed to test the relative merits of the concept of a "forward-going" tendency as opposed to the concept of "centrifugal swing" in explaining the naïve rat's behavior at a choice-point. From a consideration of the data obtained it is pointed out that when the disturbing factor of "positional preference" is controlled, "centrifugal swing" assumes a much greater importance than a possible "forward-going" tendency in explaining the rat's behavior at a choice-point.

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MAZE LEARNING IN RATS IN THE ABSENCE OF SPECIFIC INTRA- AND EXTRA-MAZE STIMULI

BY

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MAZE LEARNING IN RATS IN THE ABSENCE OF SPECIFIC INTRA- AND EXTRA-MAZE STIMULI

BY

C. H. HONZIK

INTRODUCTION

On the basis of results of a previous experiment⁽¹⁾ it was concluded (1) that maze learning in rats is not necessarily dependent on the formation of simple stimulus-response connections and (2) that accurate maze running is not a purely kinaesthetic chain-reflex phenomenon. The suggestion was made that maze learning in rats, even under the ordinary conditions of an unchanging maze, contains elements of what in human beings we call rational learning.

The present investigation is a continuation of the previous study, although a maze of a different pattern is used for two of the three groups of rats utilized. It will not, however, be amiss to repeat in general terms the procedure and argument that hold for both studies:

If *blind* rats can learn a fairly difficult elevated multiple T-maze when the units of the maze are constantly interchanged and shifted about (the pattern being kept constant), and if, further, the rats are not disturbed in their performance when the maze is rotated in the room, it may safely be said that learning was accomplished independently of *specific* visual, tactual, olfactory, and auditory cues or stimuli. When these four types of stimuli are excluded as directive cues in the running of the maze, the rats may still be said to have learned the maze kinaesthetically; that is, they have learned a kinaesthetic pattern which unrolls itself, as it were, when the rats are placed on the maze. If, then, the running of the maze is purely kinaesthetic, a disruption of the kinaesthetic pattern should perceptibly upset and confuse the rats, increasing significantly their error scores. Such a disruption can be simply accomplished by inserting in the maze at desired points a block and a short new path which will force the rats to leave out a part of the maze and cause them to jump, figuratively speaking, from an earlier to a later part of the maze. If now

the rats are able to make this so-called "short cut" without confusion—if they run the later part of the maze immediately after the short cut* with no significant increase in errors—we are compelled to conclude that they are not running the maze purely kinaesthetically, or, in other words, that kinaesthesia is not operating as a factor necessary to correct running. This conclusion is made certain when we consider that exploration of the maze after the short cut, to pick up kinaesthetic cues, would inevitably lead to blind entrances and cause a significant increase in the number of errors. Visual stimuli and specific tactual, olfactory, and auditory stimuli being now eliminated as necessary factors in the running of the normal pattern of the maze, and pure kinaesthetic running being excluded by the performance on the "short cuts," we conclude that the rats somehow, independently of specific sensory cues, "know" where they are after making the short cut; or, to express the matter in Lashley's words, we conclude that "the maze habit cannot be interpreted as a series of kinaesthetic-motor reflexes [nor as a series of stimulus-response connections] but must be referred to some intraneural mechanism capable of producing an integrated sequence of movements in the absence of directive sensory cues."

EXPERIMENT I

THE MAZE FOR GROUP III

A group of 17 rats (Group III) was trained on the maze used in the previous study. This maze was of the elevated type (fig. 1); the rails or pathways were of finished pine 2 inches wide and stood 30 inches above the floor, being supported by $1\frac{3}{4}$ inch \times $1\frac{3}{4}$ inch uprights. At points indicated in figure 1, gates were inserted to prevent retracing. These gates were of $\frac{1}{4}$ inch wire mesh. By means of stout wire pivots at the top, they were made to swing between two uprights fastened to the rails. The gates were thus parts of the units to which they were fastened; and they were moved about with the units, as will be explained later. A short nail in one of the gate uprights prevented a gate from swinging backward, and, according as the gate was placed on one or the other side of the nail, the gate could be made to swing in either direction. The gate could also be easily removed, leaving only the two uprights in place.

The maze contained 19 blinds and these varied in length from 11 to 14 inches. The true path measured 59 feet. The units of the

* To Dr. R. C. Tryon belongs the credit of first suggesting and trying the method of "short cutting" to disrupt a kinaesthetic sequence, if such exists.⁽⁷⁾ Instead of using blind rats, Tryon ran his rats in complete darkness. His startling results suggested this further research.

concerned, without changing the pattern. If there were directive stimuli, tactual or olfactory, specifically located at the various choice points in the rat's path, interchanging the units would inevitably disturb these stimuli and make dependence on them of no avail. Since the floor on which the maze was set was rather uneven, the junction of any two units varied from one interchange of units to another, and this had the effect of further increasing the confusion of tactual stimuli with the shifting of units. It should be mentioned also that besides being shifted from place to place the units were often turned end for end so that what had been a blind was now a part of the true path, and vice versa. In such shifts units with gates would have the gates in the blind, and this necessitated removal of the wire mesh or removal of the nail to let the gate swing both ways so as to make possible a return in the event of an error. It is clear that with this procedure the effect was to confuse tactual and olfactory stimuli completely and probably to add new distracting stimuli because of the unevenness of the floor and the presence in many units of gates in blinds, these gates being in such positions that they could be felt by the vibrissae of the rats when they stood at the choice points.

METHODS AND ANIMALS

The rats were blinded by removal of the eyeballs, a simple operation that had no perceptible bad effect on the rats' health or vigor. Preliminary training was begun five days after the operation. This preliminary training required six days and consisted of three runs over a straightaway on the first day and then from four to seven runs daily on longer set-ups with corners and gates. The rats were then started on the maze proper (fig. 1).

Two runs daily were given on the maze up to the twenty-first day, and thereafter three runs daily. The animals were fed only in the food box at the end of the maze and the food was so apportioned that they were always hungry and eager for food. Frequent weighing was used as a check against too great a loss in weight.

An entrance into a blind to within four inches of the end of the blind was counted an error. This means that in the longer blinds (blinds varied from 11 to 14 inches) the rat could enter a blind to its full body length, but if its vibrissae did not reach the end of the blind—and this could not occur unless the rat came within less

than four inches of the end—such an entrance was not counted an error. Ignoring in this way partial blind entrances may be thought a low criterion for error scoring. Reasons for the procedure are as follows. If a blind rat turns before it has reached the end of the blind, we may fairly say that without direct sensory evidence of having entered a blind it has checked an error. Visual evidence was precluded, since the rats were blind; tactual and olfactory evidence could not be depended on, because units were shifted and turned end for end. In the short cut trials, when the rats came to choice points immediately after making the short cut, hesitation and uncertainty in behavior was frequently observed. Often an entrance into a blind was begun but quickly checked. Since units were interchanged in all short cut trials, specific sensory stimuli could not be causes for this checking of false turns, and we may say that in such entrances a complete error was not made. Some danger lay in the possibility of inaccurate observation of the rat's distance from the end of the blind, and it should be said that if there was any doubt the entrance was scored an error. Full errors, as just defined, were indicated by the numbers of the blinds in which they were made; thus not only the number of errors but also the exact location of each error was recorded for every run.

RESULTS FOR GROUP III

Group III consisted of 13 males and 4 females, ranging in age from 2 to 4 months at the beginning of training. For the first two days of training (two runs daily) the maze was unchanged. On the third day, 13 of the 26 units in the maze were interchanged and turned end for end. Figure 2 gives the error curve for the group. A rapid drop in the curve for the first two days will be noticed. It is certain from results of the previous study and from other maze studies that this descent of the curve would have continued on the third, fourth, and perhaps the fifth day, if the maze had been left unchanged. The sudden shifting of 13 maze units on the third day checked this drop of the curve. Thereafter, because no less than 10 (usually more) units were shifted for each and every run, the curve is jagged and its descent extremely slow. Shifting of units was so arranged that each day all the units changed place, about one-half for the first run, the other half for

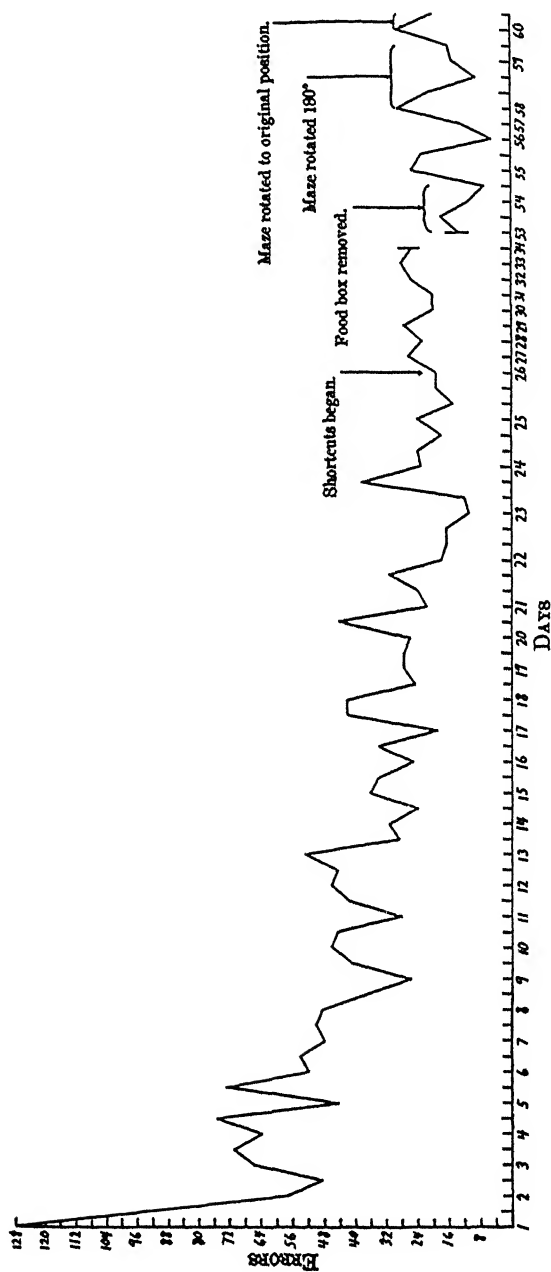


Fig. 2. Error curve for entire maze.

the second. To reach what looked like a plateau required 25 days of running, or 55 runs. It was thought that increasing the number of daily runs might hasten learning, so from the twenty-first day on three runs daily were given.

The checking of the initial drop in the curve due to interchange of units and the subsequent slow descent of the curve raise an important question. W. S. Hunter,⁽²⁾ from similar results on his own mazes, has argued that the stimuli from the maze are directive; they become cues in the true sense because they call forth definite behaviors. Confusion of the stimuli by shifting of units causes disruption of maze performance, or, as in our experiment, a retardation in learning, because, with constant shifting, stimuli cannot become directive. But it is possible to argue, perhaps less plausibly, that shifting of units (and of stimuli) is merely distractive. Thus, disruption of maze performance could be said to result from distraction ensuing from a change in the habitual arrangement of stimuli. Against this view may be advanced the argument that negative adaptation to this sort of distraction should be acquired and that our curves, after the initial slowing down, should drop more rapidly than they have done. It is clear, from these opposing interpretations, that the question of the function of intra-maze stimuli in maze performance is not conclusively answered by our results or by Hunter's. It is also quite clear that we have here a question of fundamental importance in the general problem of maze learning.

But whatever the true function of intra-maze stimuli may be, the rats undoubtedly learned the maze to a fair degree of accuracy. Thus on the twenty-third and twenty-fourth days the error records (3 runs daily) were, for the six trials, 11, 12, 38, 23, 24, and 18 errors respectively; or, expressed as average scores per rat: 0.65, 0.71, 2.24, 1.35, 1.41, and 1.10 errors respectively. Since there were 19 blinds in the maze, even the highest average score (2.24 errors) indicates a high degree of accuracy of performance. We may conclude that the rats learned the maze independently of specific tactical and olfactory stimuli from the maze, or, in other words, that accurate running was not a matter of simple stimulus-response connections, so far, at any rate, as intra-maze stimuli were concerned.

There remained extra-maze auditory and possibly olfactory stimuli. To check on the possible influence of these, (1) the maze was rotated first 180° from its original position, then back to its original position, and (2) the food box and food were moved to a position near blinds 7 and 9 (see fig. 1). The curve of figure 2 shows the results of these changes. Correlated with removal of food box and food, there were no significant increases in errors. Upon rotation of the maze there is an upward jump, in the error curve, from 13 to 29 errors. It is, however, very doubtful that this increase in errors was entirely due to a change in the direction of auditory stimuli. Because the maze was not on a platform, rotation could only be effected by taking the maze completely apart and setting it up again in a new place; and, because of the extreme unevenness of the floor, this procedure undoubtedly caused unusually large tactual differences at the junctions of units, i.e., the choice points. The upward jump in the error curve was most probably due to this fact. Nevertheless, the highest error score when the maze was rotated was only 4 errors greater than the highest score in the four days before rotation. It is to be noted also that there are in the error curve other upward jumps as large as and some larger than this rise of 16 errors (an average increase of 1 error per rat) which seems to be due to maze rotation. For example, on day 55 there is an upward jump of 18 errors; on day 23, 26 errors; on day 20, 18 errors. We may safely conclude that extra-maze auditory and olfactory cues did not play an appreciably significant rôle in the maze performance.

So far, we had excluded visual stimuli, prevented the operation of specific intra-maze tactual and olfactory stimuli, and shown the lack of influence of extra-maze auditory and olfactory stimuli. The possibility remained that the rats were running the maze kinaesthetically. In kinaesthetic behavior, as, for example, the playing of a very well known piece on the piano, it is generally supposed that each movement is the stimulus for a definite succeeding movement. The essence of kinaesthetic behavior is the definite, unvarying order in the sequence of movements. Disruption of the order, or any forced change in the fixed sequence, must inevitably disrupt the organism's smooth performance, and presumably the animal is compelled to fall back on external stimuli to set itself right, to

recover the habitual order of movements. In our rats such a forced disruption was effected by short cutting, that is, by forcing the rats, by means of a block and a short new path, to leave out a part of the maze. The habitual order of movements was definitely changed. But when the order of movements of the rats was thus changed there was no possibility of falling back on specific stimuli, for these were changed with the shifting of the units, and auditory and olfactory stimuli from outside the maze were found to be without influence.

Training for Group III extended over 60 days. From the twenty-first day on, as mentioned above, three runs daily were given, and on the twenty-sixth day the various short cutting trials were begun. Eleven different short cuts, as indicated in figure 1, were tried, and eight of these were given twice on widely separated days. The first run each day was always over the whole maze (such runs will hereafter be called normal pattern runs) and frequently the first two runs were of this type, followed by short cut or "put on" trials. It was necessary to give at least one, preferably two, runs each day over the complete maze, because the true path in the maze as a whole had to be maintained as a basis on which to try short cuts. A succession of short cut trials without normal pattern runs would probably have led to confusion, since this would have meant the running of changing maze patterns.

The procedure being in all essentials the same for all short cuts, one short cut trial may be described in some detail. Short cut 2-7 (see fig. 1) was given on the twenty-sixth day (fig. 2). On this day ten units of the maze were interchanged and a normal pattern run was given. A short path was then inserted between units IV and X, and two tin blocks were placed, one at a point six inches from the turn into unit V, the other six inches from the turn into blind 6. All the units from unit IX on were interchanged with other units. The rats were started from the platform and all entered unit V, as was to be expected. Encounter of the block here naturally caused some confusion; most of the rats wandered back over unit IV to the gate on unit III. It may be mentioned that this confused behavior diminished with succeeding short cut trials, as if the rats had learned to look for a short cut path whenever a block was encountered. Sooner or later, the new path to unit X was

found and taken. All the rats, on this trial, approached the block on unit IX. Our chief interest was to record the rats' behavior from this point on. Hesitations at the choice points were frequent, but no complete record was made of these; only errors as defined above were recorded. The units were again shifted and the rats run a second time on this short cut. The number of errors made in the part of the maze from blinds 7 to 19, inclusive, is to be compared with the number of errors made in the same portion on normal pattern runs, that is, when the rats ran the entire maze. Although error curves furnish easier and clearer comparisons, we present, to conserve space, a table instead. Table I gives scores for each trial of the various short cuts, and, to compare with these, eight scores on the same part of the maze when the rats ran the full normal pattern. Table 1 is to be read as follows. Short cut 2-7 (blinds 7-19) was given three times, twice on the twenty-sixth day and once on the forty-ninth day (right-hand column). Error scores made on these trials are, in the same order, 15, 22, and 13 (third column). Error scores made on the same part of the maze, namely, blinds 7-19, *when the rats ran the normal pattern*, are 29, 17, 18, 28, 11, 6, 12, and 11 (second column). These eight scores are taken from the eight normal pattern runs preceding the first 2-7 short cut trial, and are therefore only sample scores, since there were many more normal pattern runs, but these scores are representative of normal pattern performance on blinds 7 to 19. It will be noted that the highest score for short cut 2-7 (22 errors) is well below the highest normal pattern score (29 errors). We may therefore say that this short cut was executed within the criterion of correct performance. Whatever confusion the short cut may have caused, it was certainly not sufficient to increase the errors above the usual records when the rats ran the whole maze. The data of table 2 indicate that the rats did not explore more than usual; dependence on specific tactual and olfactory stimuli from the maze was impossible, because the units had been shifted; extra-maze auditory and olfactory stimuli had been found without effect. We may conclude tentatively that the rats in some sense "knew" where they were after taking the short cut path, and that by virtue of this "knowledge" they ran the rest of the maze with their usual accuracy.

TABLE 1

	Normal pattern scores	Short cut scores	Days when short cuts were given
Short cut 2-7 (Blinds 7-19)	29, 17, 18, 28, 11, 6, 12, 11	15, 22, 13	26, 26, 49
Short cut 8-12 (Blinds 12-19)	5, 13, 9, 5, 4, 2, 5, 9	18, 6, 20, 4, 14	27, 27, 50, 51, 51
Short cut 2-5 (Blinds 5-19)	22, 26, 15, 14, 19, 12, 19, 21	24, 18, 21	28, 28, 52
Short cut 6-14 (Blinds 14-19)	2, 1, 0, 1, 0, 5, 0, 4	18, 13, 5, 8, 5	29, 29, 30, 30, 57
Short cut 8-14 (Blinds 14-19)	0, 1, 0, 5, 0, 4, 2, 5	3, 2	31, 31
Short cut 3-6 (Blinds 6-19)	23, 19, 34, 26, 23, 18, 14, 24	29, 15, 16	32, 32, 54
Short cut 2-15 (Blinds 15-19)	0, 5, 0, 2, 1, 5, 0, 1	10, 5, 6	33, 33, 59
Short cut end 6-15 (Blinds 15-19)	5, 0, 2, 1, 5, 0, 1, 1	0, 2	37, 37
Short cut 3-mid 8 (Blinds 6-19)	19, 21, 23, 18, 14, 24, 17, 19	20, 20, 7	34, 34, 55
Short cut 1-15 (Blinds 15-19)	0, 2, 1, 5, 0, 1, 1, 0	10, 2, 1	35, 35, 57
Short cut mid 17-15 (Blinds 15-19)	2, 0, 1, 5, 0, 6, 1, 0	6, 2	36, 36

TABLE 2

Short cut 2-7										
Blinds*		7	8	9	10	11	13	14	....	Totals
Trial 1	Errors	5	3	....	2	....	5	....	....	15
Trial 2	.....	1	3	1	4	1	11	1	....	22
Trial 3	.....	1	5	2	5	....	....	....	....	13
	Totals	7	11	3	11	1	16	1	....	50
									
Short cut 8-12										
Blinds		12	13	14	17	....	....	....	....
Trial 1	Errors	3	12	....	3	....	....	....	....	18
Trial 2	.....	2	3	....	1	....	....	....	....	6
Trial 3	.....	6	13	1	....	....	....	....	....	20
Trial 4	.....	1	3	....	....	....	....	....	....	4
Trial 5	.....	2	12	....	....	....	....	....	....	14
	Totals	14	43	1	4	....	....	....	....	62
									
Short cut 2-5										
Blinds		5	6	7	8	9	10	11	13	
Trial 1	Errors	8	....	....	7	1	4	....	4	24
Trial 2	.....	....	1	1	9	1	2	1	3	18
Trial 3	.....	6	2	....	5	....	5	1	2	21
	Totals	14	3	1	21	2	11	2	9	63
									
Short cut 6-14										
Blinds		14	16	17	....	....	....	....	....
Trial 1	Errors	12	4	2	....	....	....	....	....	18
Trial 2	.....	8	2	3	....	....	....	....	....	13
Trial 3	.....	2	3	....	....	....	....	....	....	5
Trial 4	.....	7	1	....	....	....	....	....	....	8
Trial 5	.....	3	....	2	....	....	....	....	....	5
	Totals	32	10	7	....	....	....	....	....	49
									

* Blinds containing no errors, for example, blinds 18 and 19, are not indicated in the table.

TABLE 2—(Concluded)

Short cut 1-15											
Blinds		16	17	....	....	....	....	....	....	Totals	Number of rats making errors
Trial 1	Errors	6	4	....	....	....	....	....	....	10	8
Trial 2	.....	1	1	....	....	....	....	....	....	2	2
Trial 3	.....	1	....	....	....	....	....	....	....	1	1
	Totals	8	5	....	....	....	....	....	....	13	....

Short cut mid 17-15											
Blinds		15	17	....	....	....	....	....	....
Trial 1	Errors	4	2	....	....	....	....	....	....	6	5
Trial 2	.....	1	1	....	....	....	....	....	....	2	1
	Totals	5	3	....	....	....	....	....	....	8	....

Short cut end 6-15											
Blinds		17	....	....	....	....	....	....	....
Trial 1	Errors	....	....	....	....	....	....	....	....	....	....
Trial 2	.....	4	....	....	....	....	....	....	....	4	4
	Totals	4	....	....	....	....	....	....	....	4	....

It is also of interest to know in what blinds the errors were made on short cut trials, and how many rats of the seventeen made errors. This information is contained in table 2, which is to be read as follows: On the first trial of short cut 2-7, blind 7 had 5 errors, blind 8, 3 errors, blind 10, 2 errors, blind 13, 5 errors; and 10 rats made a total of 15 errors, which means that some of these 10 rats made more than one error while the remaining 7 rats made no errors. On the second trial, blind 7 had one error, blind 8, 3 errors, etc., and 15 rats made a total of 22 errors. The totals indicate that blind 13 was entered most frequently (16 errors), and blinds 8 and 10 next (11 errors each). If the rats had explored the maze immediately after taking the short cut, in an effort to "pick up" the kinaes-

thetic sequence, we should expect blinds 7 and 8 to account for most of the errors. Actually they account for 18 errors as against 27 errors in blinds 10 and 13. Blinds 10 and 13 were, incidentally, also difficult in the normal pattern runs.

At this point two possible arguments may be considered. The possibility that the rats might have run correctly the part of the maze following the short cut path *by chance*, was mentioned above. In the previous experiment,⁽¹⁾ in order to obtain objective evidence on this point the maze pattern following short cut 2-7 (and other short cuts) was completely changed, but the new pattern had the same number of blinds. The argument was that, if the rats were running correctly merely by chance, then they should perform equally well on any pattern. The enormous increases in errors when the maze pattern was changed demonstrated conclusively that chance could not account for the rats' performance. Because of this clear demonstration it was deemed unnecessary to repeat the procedure in the present study.

The other argument is that, in spite of the constant shifting of units, some intra- or extra-maze stimuli by which the rats could be guided, still remained. If there were such directive stimuli, it is reasonable to suppose that the rats could be guided by them from any point within the maze to the end of the maze. This was tested by the following procedure: The rats were placed by hand on the end of blind 6, which is the place they reach after going through the short cut path, and allowed to run to the end. A block was placed, as in short cut 2-7, on unit IX six inches from the turn into blind 6. Units were changed as for short cut runs. The starting platform was not used. Table 3 gives the results for two such "put on" runs; the error scores are 32 and 44 as against scores of 15, 22, and 13 for the corresponding short cut 2-7. This excess of "put on" scores over short cut scores indicates considerable confusion, or, we may say, lack of "knowledge" of whereabouts in the maze. (Similar "put on" runs, corresponding to each of the other ten short cuts, were tried, and in all the runs there were significant increases in errors—see below.) We may safely conclude that if any directive stimuli remained after unit-shifting (for both "put on" and short cut runs), they were insufficient for the correct guidance of the rats.

TABLE 3

	Day on which given	Errors	Errors on corresponding short cuts
Put on end of blind 6, corresponding to short cut 2-7	38 38	32 44	15, 22, 13
Put on end of blind 11, corresponding to 8-12	39 39	28 20	18, 6, 20, 4, 14
Put on end of blind 4, corresponding to 2-5	40	49	24, 18, 21
Put on far end of unit 18, corresponding to 6-14	41	18	18, 13, 5, 8, 5
Put on mid unit 17, corresponding to 8-14	42	11	3, 2
Put on mid unit 9, corresponding to 3-6	43	27	29, 15, 16
Put on food end of unit 18, corresponding to 2-15	44	10	10, 5, 6
Put on mid unit 18, corresponding to end 6-15	48	8	0, 2
Put on mid unit 8, corresponding to 3-mid 8	45	27	20, 20, 7
Put on end of unit 19, corresponding to 1-15	46	15	10, 2, 1
Put on mid unit 21, corresponding to mid 17-15	47	13	6, 2

When we ask why the large difference in error scores between the short cut and the corresponding "put on" runs, the importance of the run from the starting platform to the short cut path, plus the run along this path, becomes evident. The run from the starting platform to the short cut path was obviously essential to good performance beyond the short cut. The reason for this will become clear from the results of Experiment II.

The remaining ten short cuts (and the corresponding "put on" runs) will be briefly discussed in the order in which they were given. (For the exact location of each short cut, fig. 1 should be consulted.) Short cut 8-12 was not executed with the required accuracy in four of the five trials on which it was given. This was surprising, since on casual inspection of the maze one would judge this short cut to be easy. Of the 62 errors made in the five trials of this short cut, 43 (70 per cent) were made in blind 13 (see table 2). The error scores of the two "put on" runs, however, are higher than the short cut scores; this would indicate that confusion after the short cut was not so great as on the "put on" runs.

Short cut 2-5 was performed with the required accuracy on its three trials. The very high score of the corresponding "put on" run confirmed the fact that the run from the starting platform to the short cut path was essential to good performance thereafter.

Of the five trials of short cut 6-14, only one (the last) may be considered as done correctly. This short cut was probably so difficult because of the presence of blind 14 at the end of the short cut path. Of the total of 49 errors made on the five trials, 65 per cent were made in blind 14. Of the errors made in the "put on" run which was started on the short cut path, 77 per cent were in blind 14. That there were relatively few errors in the blinds beyond 14, namely, blinds 15 to 19, may be explained by saying that the long run over unit XVIII plus the two turns without blinds at the ends of unit XIX acted as a triple cue by which the rats "recognized" their position in the maze. The recognition, however, could not have been by means of stimuli from the units themselves, since these were changed. It is, however, possible that the long run and the turns acted as kinaesthetic cues, that is, that these re-aroused the kinaesthetic pattern. The possibility that some *short cuts* could be explained in this way will be considered in connection with short cuts that have such factors in their favor.

The two trials of short cut 8-14 come easily within our criterion of good performance. The long run on unit XVIII plus the two turns cannot be advanced as an explanation, since these come after blind 14. Of a total of 5 errors this blind accounted for only one. The "put on" run had a high score, again demonstrating the necessity of the run from the platform to the short cut. But further, of

the 11 errors made on the "put on" run, 82 per cent were in blinds 16 and 17. Thus, in this run at least, the run over long unit XVIII plus the two turns did not act as an effective cue. This conclusion is strengthened by the results of poorly executed short cut 2-15, which had the two turns but not the long run in its favor, and nevertheless had too many errors, chiefly in blind 16.

The first trial of short cut 3-6 may be considered doubtful, since its score is as high as that of the "put on" run. The remaining two trials, however, are well within the criterion. The three scores made on short cut 3-mid 8 were well below the highest normal pattern score; the corresponding "put on" run had a high score. The first trial of short cut 1-15 had too high a score; the other two trials yielded low scores. The corresponding "put on" score was high. The scores of short cuts mid 17-15 and end 6-15 were all good, the first trial of short cut end 6-15 having no errors at all. The corresponding "put on" scores were high.

Aside from the long run on unit XVIII and the two turns at either end of unit XIX mentioned above, correct performance on short cut runs might possibly take place simply as a result of the following out of an acquired kinaesthetic pattern. If the sequence of turns following close after a short cut is exactly the same as the sequence of turns in the part of the maze that has been left out, the rats could run a short cut trial correctly by simply following a habitual kinaesthetic sequence. For example, the sequence of turns following short cut 2-7 is *lallall*, etc.; the sequence in the left-out portion is *rualllr*. Here, obviously, the two sequences are different, and a following out of the habitual one would not give a correct performance in the short cut trial. The two analogous sequences for short cut 2-5 are *lallal*, etc., and *lalllr*; for short cut 6-14 they are *lallalllr* and *ruallallr*. Even though the two sequences of turns were the same, a correct performance on a short cut trial would involve a disregard of the differing length of runs between turns, and this is unlikely. Inspection of the maze in figure 1 will show, however, that in no short cut are the two sequences alike, and consequently it cannot be said that the following of a learned, stereotyped sequence accounts for any correct performance on a short cut trial.

SUMMARY AND CONCLUSIONS

We may summarize the results of short cutting as follows: On two of the eleven different short cuts (8-12 and 6-14), error scores were too high to meet the required accuracy. On three short cuts (3-6, 2-15, and 1-15) scores of first trials were doubtful or definitely too high, but the scores of remaining trials for each short cut were good. On six of the eleven short cuts (2-7, 2-5, 8-14, 3-mid 8, mid 17-15, and end 6-15), scores on all trials were well within the criterion. The six corresponding "put on" run scores were high, that is, above the criterion used for short cut trials. It is evident from this that the run from the starting platform to the short cut path was essential to accurate performance beyond the short cut.

Why some short cuts should be performed correctly and others not is not at all clear from the maze used in this experiment. We may hazard the guess that the spatial characteristics of a short cut, that is, its position in the maze, have something to do with it. The character of the maze pattern following a short cut does not seem to be a determining factor, for the patterns following the six correct short cuts differ greatly one from another. Since six of the eleven short cuts were executed with the required accuracy, we conclude that rats possess in some degree the ability in question. This ability we should describe as a capacity to react effectively and with a minimum of effort, not on the basis of specific stimuli, but by the apprehending of spatial relations.

EXPERIMENT II

THE MAZE FOR GROUPS I AND II

In order to discover if possible what the spatial characteristics of a short cut may be that make it difficult or easy, an elevated maze of a simpler general outline was constructed. It was thought that a maze rectangular in outline with different arrangements of blinds in three corners might reveal something of the factors operating. Accordingly, the maze shown in figure 3 was set up. As in the other maze, the rails were of pine 2 inches wide, set on uprights 30 inches from the floor. The three long paths (units I, VIII, and XV) each measured 8 feet, and were therefore interchangeable.

Two gates on each of these long rails prevented retracing. The maze contained 14 blinds, all 12 inches in length except blind 9, which was 16 inches. The units in the corners were of two different lengths, 16 and 30 inches. Besides the units in the maze, two 8-foot rails, four 16-inch units, and six 30-inch units were constructed, and these were inserted in the maze at appropriate places when interchanging of units began. It is clear that, as in the other maze, a complete change of component parts was possible without change of maze pattern.

In a maze of this sort it was comparatively easy to make the arrangements of the blinds in the three corners differ one from another sufficiently to preclude the possibility of a rat's running correctly through one corner arrangement under the mistaken notion that it was in some other corner. Inspection of figure 3 will show that the true path at the three corners describes quite different patterns. The succession of turns in the corners is as follows: first corner, R(L)LRRL(L); second corner, (L)LRRR(L)(L); third corner, L(R)RLRL. (Letters in parentheses refer to forced turns, that is, turns without blinds.)

Specifically, the questions asked were these: (1) If the rats are short cut diagonally from one side of the rectangle to the adjacent side, thus cutting out one corner arrangement of blinds, will they react correctly in the rest of the maze? (2) If two corners are cut out by short cutting from one side to the opposite side, will the rats perform correctly? (3) Will performance after the rat has run a diagonal short cut differ from the performance after the rat has run a short cut made by removing the units in a corner and extending one side to make it join the adjacent side at right angles? In more general terms, the question was whether the rats were aware that the maze pattern formed a rectangle, and whether, by virtue of this awareness, they could execute correctly the various short cuts.

METHOD AND ANIMALS

Two groups of male rats (Groups I and II), each group composed of 13 rats, were trained over a period of 102 days. The rats ranged from 2 to 4 months in age at the beginning of training. Blinding was effected by removal of the eyeballs. Preliminary training extended over four days with 3 to 6 runs daily, first over

a straightaway, then over longer paths with turns and gates. On the maze proper two runs daily were given, and, even when short cutting was begun, the number of daily runs was never more than two. Food was always given in the food box at the end of the maze,

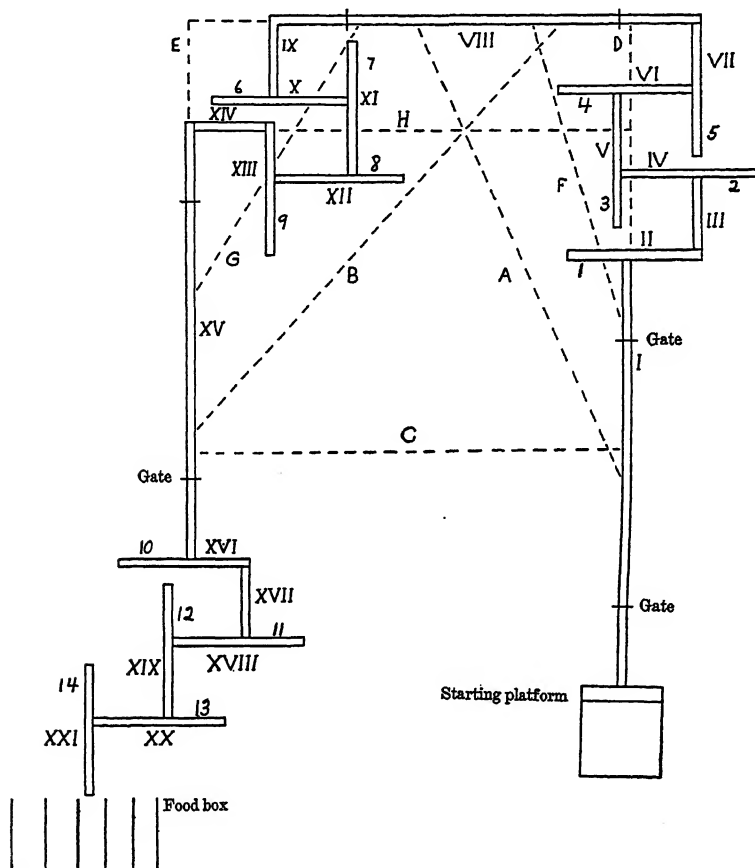


Fig. 3. Diagram of elevated maze used in Experiment II. Arabic numerals indicate blinds; roman numerals, units. Short cuts are indicated by broken lines and capital letters.

and frequent weighing served to prevent too great a loss in weight, besides indicating roughly the degree of hunger.

As in Experiment I, an entrance into a blind to within four inches of the end of the blind was counted an error. The reasons

for this scoring criterion given in Experiment I hold here also. If the rat's distance from the end of a blind was in doubt, the entrance was scored as an error. Errors were indicated by the numbers of the blinds in which they were made.

RESULTS FOR GROUPS I AND II

Results for Groups I and II up to the point when short cutting began will be treated separately. This is because Group II was started on the maze two days after Group I, and thus Group I was four runs ahead of Group II. But before short cutting began, the two groups were equalized by running Group I only once a day for four days so that this group then had the same number of runs as Group II. Thereafter, all short cuts and other runs were given the two groups on the same days, and results on short cuts and other runs for the two groups have accordingly been lumped.

Because of the long paths between the corners of the maze, that is, between the parts that required learning, it was thought that learning would be somewhat retarded. It was therefore surprising to find a very steep descent in the error curves of both groups (fig. 4). By the end of the third day (six runs) the rats had apparently learned the maze; from that day on both curves are plateaued, the only noticeable deviations being the two runs on day 7 of Group II. It is perhaps unnecessary to remark that during this period the maze was not changed in any way. We wished to see what effect the sudden interchanging of all maze units would have on the rats' performance and thereby possibly to gain some light on the rôle of intra-maze stimuli.

On the thirteenth day for Group I and the eleventh day for Group II (because Group II was two days behind Group I) every unit of the maze was interchanged with some other appropriate unit. This change was made for the second daily run, that is, between the first and second runs of the day. The effect on both groups was startling. Group I made more errors than it had on the first trial; Group II made almost as many (fig. 4). It was as if a new maze had been suddenly presented. Whatever the exact rôle of intra-maze stimuli may be in respect to blind rats, it was obvious that the changing of these stimuli by shifting of units had a great disruptive effect on maze performance.

Other interesting facts appeared. As was mentioned above, the interchange of units was made for the second daily run of days 11 and 13. The maze was then left untouched for the first run of the succeeding day. But for the second run of the succeeding day the units were again completely interchanged. Thus the shifting of units took place *between the two runs of each day* up to day 21 (day 19 for Group II). Considering for the moment only the curve of Group I, we note a very regular up and down zigzagging from days 13 to 21. It will be noticed that all the points marked "2" are above the points marked "1"; the second run of each day, that is, the run immediately following an interchange of units, always had more errors than the first daily run, which was made on the maze unchanged from the previous day. One may interpret this by saying that on the first run of each day (and the last run of the preceding day) the rats had experienced groups of stimuli (tactual, kinaesthetic, and olfactory) in definite spatial relations and that the disturbance of the general stimulus-pattern resulting from the unit-shifting for the second daily run was the cause of the increase in errors. The question whether the increase in number of blind entrances was due to distraction or to the fact that the stimuli had taken on some directive value during the two previous runs, is not answered by the results just described, and we shall presently show that this question is probably beside the point.

On the above interpretation as a basis, a prediction might be made that interchanging units *between days* instead of between the two daily runs should cause the following changes in the error curves: (1) the first runs of each day should have more errors than the second runs, and (2) the up and down zigzags should be of smaller magnitude, since the rats had a longer period (24 hours) in which to "forget" how the stimuli were arranged on the preceding day. Actually, the curve bears out these predictions. The points marked "1" are all higher than the points marked "2." (The reversal in the relative positions of the 1's and the 2's caused by the change in time of unit-shifting is easily seen by following the broken line in fig. 4, Group I). And the up and down excursions of the curve are in general smaller.

The facts, then, are that, when unit-shifting occurred between the two daily trials, the second trial always showed more errors

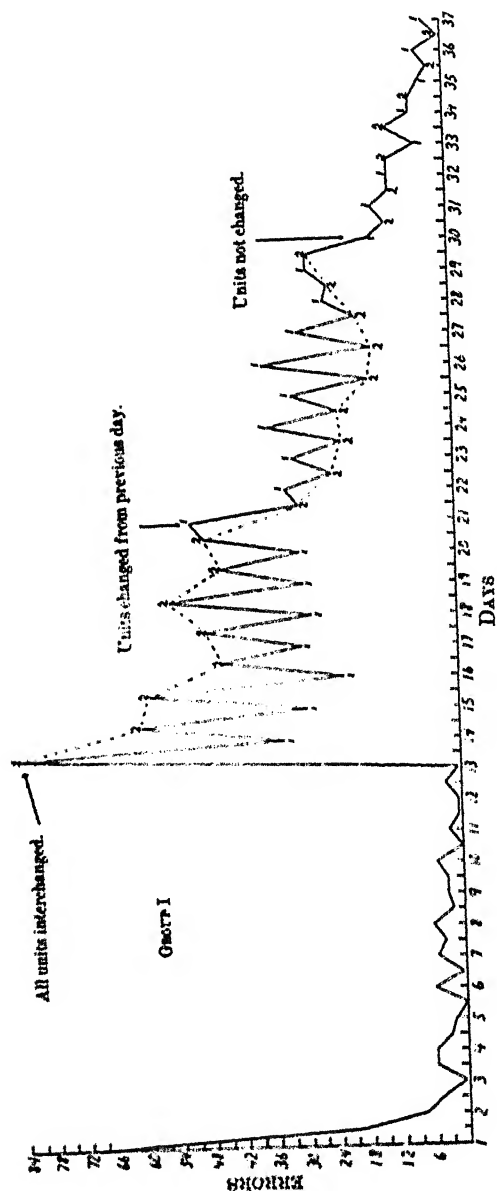


Fig. 4 (a). Error curves of Group I for entire maze.

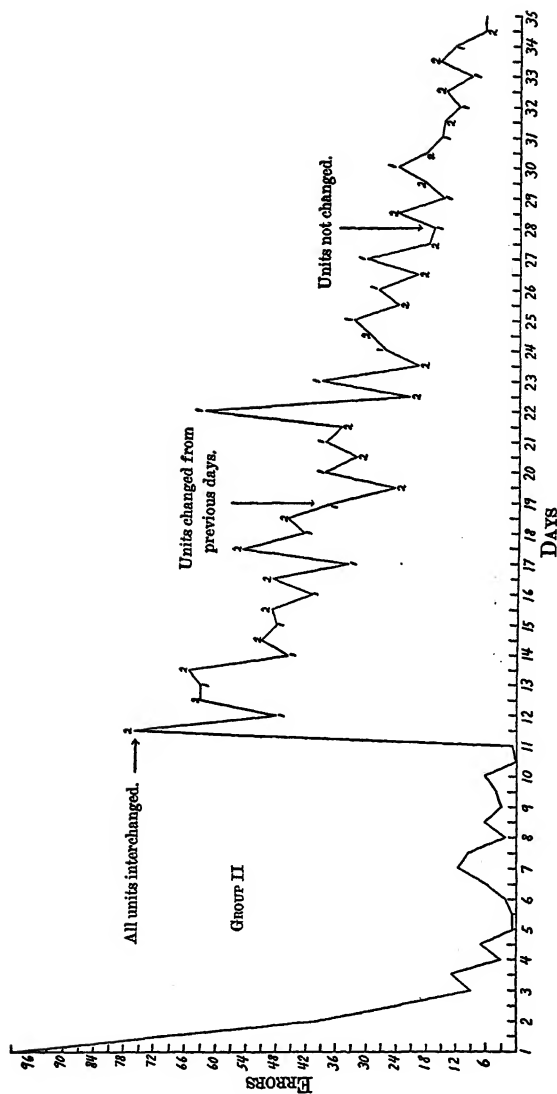


Fig. 4 (b). Error curves of Group II for entire maze.

than the first, and that when the shifting occurred between days, the first trial showed more errors than the second. We must add, however, that although the same facts also hold substantially for Group II, there are two differences between the two curves: (1) the up and down excursions of the curve of Group II are not so regular as those of the curve of Group I, and (2) on day 24 (Group II) the positions of "1" and "2" are reversed. Probably these differences are not serious, since the spatial relations of the "1" and the "2" points are, with the one exception noted, constant.

We return once more and briefly to the questions of distraction and the possible directive rôle of stimuli. It has been argued that, if the maze had been left unchanged after the first unit-shifting, the curves would have descended to their former low levels in a few runs, as is evidenced by the sharp drops on days 14 (Group I) and 12 (Group II), and that it was the continual distractions caused by interchanging of units that prevented this. On the contrary, it is equally plausible to argue that constant interchanging prevented stimuli from becoming directive. And against the distraction theory it may be further urged that habituation or negative adaptation to continual distraction, if it were really distraction, would have been acquired, and the curves would have reached plateaus much sooner than they actually did.

We have returned to this discussion, first, because of the obvious importance of the question of the rôle of stimuli in maze learning, and, secondly, because one of the theories, namely, that the stimuli are directive, has been accepted⁽²⁾ on what we believe to be entirely insufficient evidence. It appears, however, from the significant results of Lashley's researches, that the question whether or not individual stimuli are directive, in the sense that each response is connected in some way with a specific stimulus, is beside the point, that it is an unreal question. Nor, it seems, can we attribute the great disturbance in maze performance following the disturbance of stimuli to distraction in the usual meaning of the term. Lashley writes:

We may state as a general principle that the stimulus to any reaction above the level of a spinal reflex involves, not the excitation of certain definite sensory cells, but the excitation of any cells of a system in certain ratios, and that response may be given to the ratio, even though the particular cells involved

have not previously been excited in the same way during the formation of the habitual reaction.⁽⁴⁾

Though this was written specifically of visual-perceptual habits, the principle applies to all types of habits. In another place⁽⁵⁾ Lashley writes:

...I believe that in every reaction, above the level of a spinal reflex to protopathic stimulation, the adequate stimulus is a pattern which is effective when applied anywhere upon the sensory surface and the motor response involves an equally variable grouping of motor neurons. . . . We have seen that the adequate stimulus in such cases [habits based on vision, kinaesthesia, and touch] is not the specific cells activated, but the pattern of excitation which may shift over the sensory surface and likewise over the cortical field. In such a pattern the relative intensity, distance of separation, and frequency of excitations seem to be the only constant factors.

It seems clear that a reaction is made not to individual and specific stimuli but to patterns of stimuli. We cannot then speak of directive stimuli in the sense that each stimulus calls out a particular response. The integrated response of running the maze is made to a stimulus pattern or perhaps to groups of stimuli that are patterned in definite ways. It is probable that, as the rat learns a maze, complex integrations of visual, tactual, olfactory, and kinaesthetic stimuli are formed. Visual stimuli being excluded for our rats, integrations were probably established through tactual, kinaesthetic, and olfactory stimuli. The sudden disturbance of tactual and olfactory stimuli by unit-shifting had the effect of disrupting completely the stimulus groups that formed the basis for correct response. Kinaesthetic stimuli alone were not sufficient after such a disruption, and the maze habit had to be re-formed on the basis of new integrations. If this interpretation is true, it is clear that we cannot speak of distraction as the cause of maze-habit disturbance following unit-shifting.

One further point remains to be mentioned regarding the error curves of Groups I and II. These curves, in spite of their great irregularity, show a steady, although slow, descent. The maze was undoubtedly being learned, albeit slowly. On the three days preceding day 30 (Group I) and day 28 (Group II) the error scores for the groups are: Group I, 29, 18, 24, 23, 27, and 27 errors; Group II, 32, 24, 28, 20, 30, and 18 errors. Expressed as average scores per rat on single runs these are: Group I, 2.23, 1.38, 1.85, 1.77, 2.08,

and 2.08 errors; Group II, 2.46, 1.85, 2.15, 1.54, 2.31, and 1.38 errors. Thus the average errors per rat ranged from slightly over one to two and one-half errors on a fourteen-blind maze. We may say that the rats learned the maze though not with a high degree of accuracy.

TABLE 4

	Scores	Days		Scores	Days
Before rotation	35	70	Maze rotated 90°	40	82
	33	71		37	
	32	72	Maze rotated 180° from original position	42	83
	25	73		41	
	31	74		42	84
	23	75		37	
	25	76	Maze turned back to original position	32	85
	17	77		31	
	31	78		34	86
	18	79		24	
	21	80		32	87
	27	81		26	

Beginning with day 30 (Group I) and day 28 (Group II) unit-interchanging was discontinued for eight days, the object being to see if this would hasten learning, that is, the elimination of errors. It did not do so, and the reason was that approximately half the rats had apparently acquired, during the unit-shifting period, stereotyped errors, chiefly in blinds 2, 9, and 10. But the up and down excursions of the curves were noticeably decreased, confirming the fact that such excursions had resulted from interchanging of units.

Before proceeding to the results on short cut trials it will be well to dispose of the matter of maze rotation, which was used as a

check on the possible influence of extra-maze olfactory and auditory stimuli. The maze was rotated first 90° counter-clockwise, then another 90° counter-clockwise (180° from original position), and finally back to the original position. Instead of an error curve to show the effects of this rotation, we present table 4, which gives a number of error scores (for the group of 26 rats on the whole maze) before and after rotation.

When the maze was rotated 90° there was an increase of 5 errors over the highest score before rotation (from 35 to 40 errors). With the next rotation the highest score was 42 errors. As with the maze of Experiment I, rotation could be effected only by taking the maze apart and setting it up again in a new position; and, because of the unevenness of the floor, it is certain that discrepancies occurred at the junctions of units, and that these discrepancies were not present when units were interchanged while the maze was in its normal position. The slight increases in error scores may easily be due to these unusual tactual stimuli and not to directional change of extra-maze auditory or olfactory stimuli.

RESULTS ON SHORT CUT RUNS

Short cutting was begun on day 47, by which time, as explained above, the two groups were equalized as to number of runs. From now on the two groups will accordingly be treated as one. Eight different short cuts were tried: short cut 1-8, by a long diagonal (marked *A* in fig. 3, which should be consulted for location of short cuts); short cut 8-15, by a long diagonal (marked *B*); short cut 1-15, from middle of unit I (*C*); short cut 1-8, at right angles (*D*); short cut 8-15, at right angles (*E*); short cut 1-8, by a short diagonal (*F*); short cut 8-15, by a short diagonal (*G*); and short cut 1-15, from unit I extended (*H*).

One short cut and its results will be described in detail before the others are considered. The first trial of short cut 1-8 by a long diagonal (*A*) was given on day 47 (fig. 5). All the units of the maze were first interchanged, including the units of corner 1 (the sets of blinds at the three corners of the maze will be designated, for convenience, corners 1, 2, and 3, in the order in which they are encountered from starting platform to food box). One of the 8-foot rails plus a 16-inch rail was placed in a position indicated by the

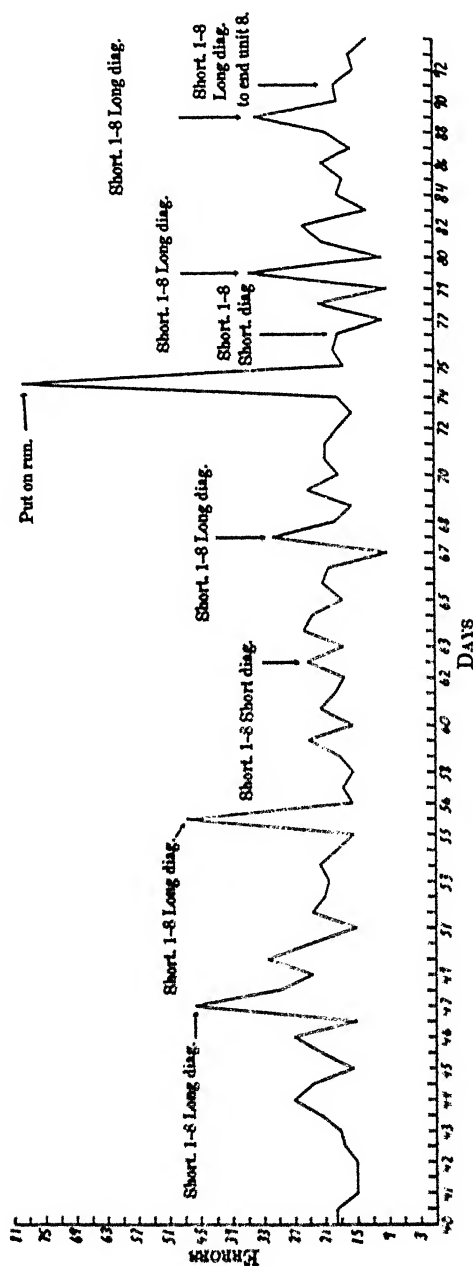


Fig. 5. Error curve for short cut 1-8 by a long diagonal and by a short diagonal.

broken line (A) in figure 3. Two blocks made of tin were placed, one on unit I, the other on unit VIII, each about six inches from the points where the diagonal short cut path joined units I and VIII. The 26 rats (Groups I and II consolidated) were run, and the errors in blinds 6 to 14, inclusive, were carefully noted. The error score for the group of 26 rats in blinds 6 to 14 is to be compared with the scores made in the *same* part of the maze when the whole maze was run, that is, in normal pattern runs. This comparison is shown in figure 5. As in Experiment I, a short cut is considered correctly performed only when its error score does not exceed the highest normal pattern score for the same part of the maze. It is clear (fig. 5) that the first trial of this short cut was not executed with the required accuracy; the short cut score (46 errors) exceeds the highest normal pattern score (27 errors) by 19 errors.

The error curves of figures 5 to 9, which show performances on short cut trials and on "put on" runs, were constructed in the following way: The blinds following any particular short cut were taken, and the errors made in these blinds *when the rats ran the full normal maze pattern* were counted. The first part of each curve shows their performance on a particular part of the maze for normal pattern runs. Next after this part, and as a continuation of it, the curve shows the number of errors made in the same part of the maze when the particular short cut under consideration was given. Thus a direct comparison can be made between performances on a specified part of the maze for short cut and for normal pattern runs. Because each short cut was given more than once there are parts of the curves between short cuts that represent performance on normal pattern runs for the appropriate part of the maze. And in the period of time between any two trials of a particular short cut, other short cuts were given, but these are not represented on the same curve, since these other short cuts cover different parts of the maze. Because normal pattern runs following short cut trials may be disturbed (that is, error scores increased) by the preceding short cut runs, and thus there may be produced abnormally high normal-pattern scores with which short cut scores must be compared, each curve contains a part representing normal pattern scores *before short cut trials were begun*. In-

spection of the five curves will show that in each curve the highest normal pattern score comes, not in the period during which short cut trials were given, but in the period before day 47, that is, before short cut trials were begun.

Short cut 1-8, by a long diagonal, was repeated on days 55, 67, 79, and 88 (fig. 5), and on all these trials the errors were too high to come within our criterion. Table 5 shows that on the five trials of this short cut, 72 errors were made in blind 6, 69 errors in blind 9, 23 errors in blind 8, and relatively few errors in the remaining blinds. The reason for this distribution of errors is as yet largely a matter of guesswork; one may, however, plausibly assume that the large number of errors in blind 6 occurred because the first correct turn in corner 1 is to the right and the rats were under the mistaken notion that they were at corner 1 instead of corner 2, and accordingly turned right into blind 6. From table 5 we note also that, on the first trial, 22 of the 26 rats made one or more errors, 22 rats made errors on the second trial, 15 rats on the third trial, 19 rats on the fourth, etc. Inspection of individual error scores reveals the fact that two of the 26 rats, namely rats W2 and W18, made perfect scores (no errors) on all five trials of this short cut. This confirms what one would expect, that rats vary in their ability to execute short cuts correctly. On any particular short cut trial, some rats will make many errors, some no errors. This means that when we lump the results of a group of rats, as we do here, (1) the good performances of able rats are obscured, and (2) the performances of the poorest rats determine disproportionately the performance of the group, since able rats can do no better, whereas the error scores of the poor rats are limited only by the number of blinds. Thus the performance on any short cut is largely the performance of the poorest rats. The remedy for this would be consideration of individual scores, individual error curves, etc., but the great practical difficulties of this procedure outweigh its advantages.

Finally, we must note the performance on the "put on" run that corresponds to short cut 1-8 by a long diagonal (fig. 5). This type of run, as explained under Experiment I, began at the point where the short cut path of the corresponding short cut ended, in this run at the point where the diagonal path joined unit VIII. The

rats were placed by hand on unit VIII at this point. A block was used to prevent their running toward corner 1. The very high score on this run—32 errors above the highest short cut score—indicates that the rats were considerably more confused on the “put on” run than on the corresponding short cut run, even though the performance on the short cut run was not good enough to come within our criterion. It will be recalled from Experiment I that the run from the starting platform to the short cut path and the running of the path were found necessary for accurate performance in the maze beyond the short cut path. This finding was confirmed by all the “put on” runs of the present experiment.

We may now consider the seven remaining short cuts in the order given. Three trials on short cut 8-15 by a long diagonal (*B* in fig. 3) were given, on days 48, 55, and 70, and for two trials the scores were higher than the highest normal pattern score (fig. 6). Table 3 shows that 31 errors (70 per cent) of the total 45 errors were made in blind 10. The high score on the corresponding “put on” run indicated that confusion was less, or fewer rats were confused, on the short cut run than on the “put on” run.

Short cut 1-15 from the middle of unit I (*C*) had four trials, on days 49, 57, 79 and 99 (fig. 7), and all the scores were too high. Of a total of 112 errors, 67 (60 per cent) were made in blind 10 (table 5). The corresponding “put on” run had a score of 38 errors, only 6 errors above the highest short cut score.

The next short cut was 1-8, at right angles (*D*); five trials were given, on days 51, 58, 72, 81, and 91 (fig. 8). The error curve for this short cut shows all five scores well within the criterion. This was surprising, since the part of the maze run through after this short cut is exactly the same as that run through in short cut 1-8 by a *long diagonal*, except that in short cut 1-8 at right angles there are *longer runs on units I and VIII*. It will be recalled that short cut 1-8 by a long diagonal was never correctly executed (fig. 5). Why this difference? Before considering possible explanations, let us see what occurred on short cut 8-15 at right angles and compare the performance on this short cut with that on short cut 8-15 by a long diagonal.

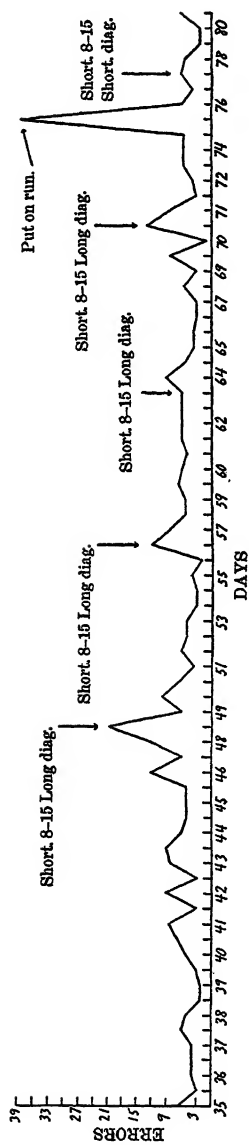


Fig. 6. Error curve for short cut 8-15 by a long diagonal and by a short diagonal.

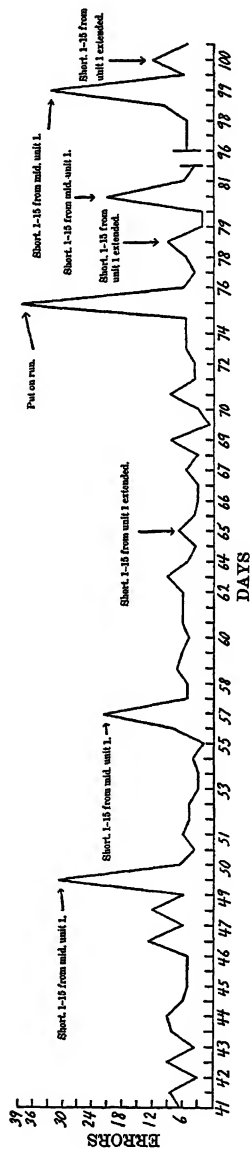


Fig. 7. Error curve for short cut 1-15 from the middle of unit I and from unit I extended.

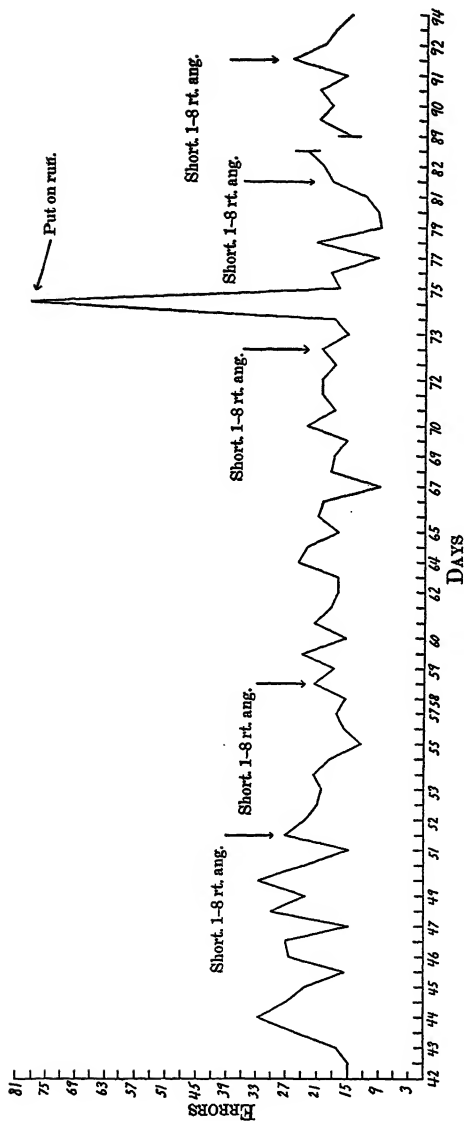


Fig. 8. Error curve for short cut 1-8 at right angles.

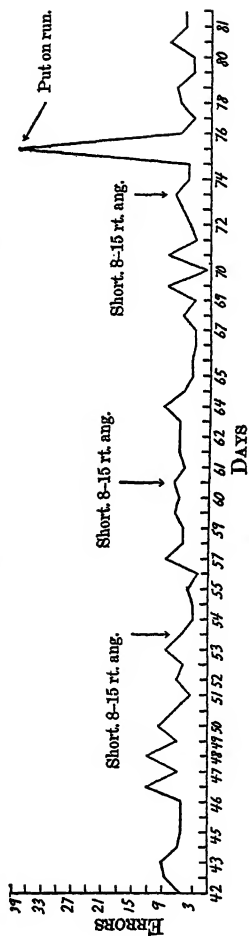


Fig. 9. Error curve for short cut 8-15 at right angles.

Short cut 8-15 at right angles (*E*) was tried three times, on days 53, 60, and 72 (fig. 9). Again we find all the scores within the criterion. (The "put on" score was very high.) The only difference between this short cut and 8-15 by a long diagonal is that there are longer runs on units VIII and XV. (It cannot be said that the right-angled short cuts were correctly performed because they came later in training when the rats were more familiar with the maze, for, if this were so, the still later, that is, the third, fourth, and fifth trials of the long-diagonal short cuts should have been correctly executed, but they were not—figs. 5 and 6.) It thus appeared that the differences in performance between short cut 1-8 by a long diagonal and short cut 1-8 at right angles, and between short cut 8-15 by a long diagonal and short cut 8-15 at right angles were due to the longer runs on units I, VIII, and XV in the right-angled short cuts. In searching for some reason why these longer runs should cause such obvious differences in performance, it occurred to the writer that the long-diagonal short cuts considerably distort the rectangularity of the general maze pattern. A glance at the diagram of the maze (fig. 3) will show that short cut 1-8 by a long diagonal (*A*) gives the maze a roughly triangular shape. So also does short cut 8-15 by a long diagonal (*B*). This distortion of the spatial relations of the long paths in the maze, it seemed, brought about the incorrect performances on the long-diagonal short cuts.

We sought to test this hypothesis in the following ways. A *shorter* diagonal from unit I to unit VIII, it was reasoned, would not greatly distort the rectangularity of the maze, since the normal runs on units I and VIII would not be greatly shortened. Such a short cut would obviously approach short cut 1-8 at right angles in its preservation of the rectangular shape of the maze. For this short cut the units in corner 1 had to be removed to make room for the short diagonal, but otherwise the usual short cut procedure was followed. Two trials were given, on days 62 and 75 (fig. 5). For both trials the scores were within the criterion; inspection of the curve in figure 5 reveals the unmistakable difference in performance on this short cut and the short cut by the long diagonal. Performance thus checked with our theory.

TABLE 5

Short cut 1-8 by a long diagonal (A)

Blinds*		6	7	8	9	10	11	12	Totals	Number of rats making errors
Trial 1	Errors	15	1	5	18	3	4	....	46	22
Trial 2	.....	19	1	7	16	4	....	....	47	22
Trial 3	.....	11	1	4	9	4	1	1	31	15
Trial 4	.....	14	1	3	14	2	1	....	35	19
Trial 5	.....	13	1	4	12	1	2	1	34	16
Totals		72	5	23	69	14	8	2	193	....

Short cut 8-15 by a long diagonal (B)

Blinds		10	11	12	13	....	....	....
Trial 1	Errors	13	4	2	1	....	....	....	20	16
Trial 2	.....	8	3	....	1	....	....	....	12	11
Trial 3	.....	10	1	1	1	....	....	....	13	11
Totals		31	8	3	3	....	....	....	45	....

Short cut 1-15 from mid unit I (C)

Blinds		10	11	12	13	14	....	....
Trial 1	Errors	18	4	6	3	....	....	....	31	21
Trial 2	.....	19	2	1	....	....	....	....	22	19
Trial 3	.....	12	7	1	7	....	....	....	27	19
Trial 4	.....	18	3	7	1	3	....	....	32	23
Totals		67	16	15	11	3	....	....	112	....

Short cut 1-8 at right angles (D)

Blinds		6	7	8	9	10	11	....	
Trial 1	Errors	8	....	3	14	2	....	....	27	16
Trial 2	.....	6	....	3	10	3	....	....	22	14
Trial 3	.....	4	....	2	10	2	2	....	20	10
Trial 4	.....	3	1	3	6	2	4	....	19	9
Trial 5	.....	9	....	2	11	1	3	....	26	14
Totals		30	1	13	51	10	9	....	114	....

*Blinds containing no errors, for example, blinds 13 and 14, are not indicated in the table.

TABLE 5—(Concluded)

Short cut 8-15 at right angles (<i>E</i>)										
Blinds		10	11	12	13	....	....	....	Totals	Number of rats making errors
Trial 1	Errors	5	....	....	....	....	....	....	5	5
Trial 2	.....	3	3	....	1	....	....	....	7	5
Trial 3	.....	5	2	....	....	....	....	....	7	6
Totals		13	5	....	1	....	....	....	19	....

Short cut 1-8 by a short diagonal (<i>F</i>)									
Blinds		6	7	8	9	10	11	....
Trial 1	Errors	6	....	4	10	4	....	....	24
Trial 2	.....	5	....	2	8	1	2	....	18
Totals		11	....	6	18	5	2	....	42

Short cut 8-15 by a short diagonal (<i>G</i>)									
Blinds		10	11	12	....	....	....	....
Trial 1	Errors	6	....	....	....	....	....	....	6
Trial 2	.....	5	....	1	....	....	....	....	6
Totals		11	....	1	....	....	....	....	12

Short cut 1-15 from unit I extended (<i>H</i>)									
Blinds		10	11	12	....	....	....	....
Trial 1	Errors	5	1	1	....	....	....	....	7
Trial 2	.....	8	1	....	....	....	....	....	9
Trial 3	.....	8	2	2	....	....	....	....	12
Totals		21	4	3	....	....	....	....	28

Similarly, short cut 8-15 by a short diagonal (*G*) was next tried, on days 62 and 76. Again both scores were within the criterion, offering further confirmation of our explanation.

It will be noticed that short cut 1-15 from the middle of unit I (*C*) also distorts the rectangular shape of the maze by greatly decreasing the height of the rectangle. Performance on this short cut, it will be recalled, was poor. The same short cut, made however from unit I (extended) to the end of unit XV, would not greatly distort the rectangle and a run through it should be executed within the limits of our criterion. Such a short cut (*H*) was given three times, on days 65, 78, and 100 (fig. 7). All three scores were below the highest normal pattern score. Again the results were in harmony with our theory.

Finally, the following check was made. It was reasoned that if it was the shortness of the runs on unit I and unit VIII (as in short cut 1-8 by a long diagonal), and not merely the length of the diagonal, that caused distortion of the maze (and consequently poor performance), then a run through a short cut with a long diagonal that nevertheless preserved the normal length of runs on units I and VIII should be executed correctly. Such a short cut was offered by moving unit I four and one-half feet to the right, keeping it pointed in its normal direction. Then a long diagonal was placed from unit I in its new position to the *right end* of unit VIII. The units of corner I were removed. (We designate this "short cut I," though it does not appear in fig. 3.) One trial on this short cut was given, on day 90 (fig. 5). The score was definitely within the criterion. The same sort of short cut should have been tried on the other side of the maze, namely, from unit VIII to the end of unit XV by a long diagonal, but unfortunately the spatial limitations of the room prevented this.

When we ask why distortion of the rectangularity of the maze-shape should cause poor performance on the short cuts that produced the greatest distortion, the answer, in the light of the interpretation on pages 26 and 27, would seem to be that such maze-shape distortion is also a disturbance of stimulus patterns. Thus short cut 1-8 by a long diagonal (*A*) disturbs the stimulus pattern (1) because it truncates the integrated group of stimuli (tactual, olfactory, and kinaesthetic) that are normally received on units I

and VIII, and (2) because the angular turn from unit I to the short cut path is considerably less than a right angle, that is, the deviation from the straight course on unit I is very slight. This latter circumstance, we may say, has the effect of confusing the stimulus group of the short cut path with that of unit I. If one were to express this in mentalistic terms one would say that the rats were misled into "thinking" they were on unit I when actually they had turned into the short cut path.

The same considerations hold for short cut 8-15 by a long diagonal (*B*). Here also we have a shortening of the stimulus group of units VIII and XV, and the slight, confusing turn from the straight course on unit VIII. Short cut 1-15 from middle of unit I (*C*) has no confusing turn from the normal path, the short cut path being at right angles to unit I, but the considerable shortening of the stimulus groups of units I and XV is clearly apparent.

But to make our hypothesis of stimulus-pattern disruption adequately explanatory, certain other factors must be taken into consideration. The five different short cuts that were made either by short diagonals (*F* and *G*), or at right angles (*D* and *E*), or from the end of unit V extended (*H*), were executed within the criterion. But all these short cuts cut out one or two groups of short runs and turns, that is, the blind arrangements in corners 1 and 2, and this also must be considered disruption of stimulus patterns. Yet these short cuts were correctly performed. We seem forced to assume either that the excision of one or two blind arrangements is a stimulus-pattern disruption of a minor sort, that is, incapable of disturbing the total response, or that a particularly important integration of stimulus groups was formed between the stimulus groups of unit I and unit VIII, and between those of unit VIII and unit XV. Whatever assumption we make, the actual results on the short cut trials demonstrated that the running of the entire lengths, or at the minimum the greater part of the entire lengths, of two sides of the maze was necessary for accurate short cut performance. The running through of blind arrangements in the corners was not necessary. But this capacity of adequate response with variation (within limits) of the stimulus pattern has been demonstrated heretofore. This demonstration, in the writer's opinion, is for psychology one of the most significant results of Lash-

ley's investigations. The evidence is conclusive that, on the one hand, responses may be independent of the particular sensory cells stimulated and of specific stimuli, and, on the other hand, that habits acquired do not necessarily utilize patterns *identical* with those employed during the process of learning.

Correct performance on short cut trials such as we observed in our rats would, in human beings, be attributed by all except the extreme behaviorists to a function which we should certainly designate as mental. We should say that in human beings the ability to perform short cuts correctly would be dependent on some such mental function as the apprehension of the spatial relations of the various parts of the maze, or we may say, more broadly, that such behavior is intelligent, as opposed to behavior rigidly associated with specific stimuli and inadequate when specific stimuli or small groups of stimuli are disturbed or excluded. The capacity to respond adequately with the changing (within limits) of the stimulus pattern and even with the exclusion of groups of stimuli is of the essence of intelligent behavior. Such behavior is in general described in its mental aspect as dependent on the grasping of relations; in our experiment, spatial relations.

The results of the "put on" runs can be interpreted in terms of the foregoing theory of intelligent behavior, and that such an interpretation is possible tends to corroborate the theory. A glance at the error curves of figures 5 to 9 will show that the error score of the "put on" run invariably exceeded by a significant amount the error score of the corresponding short cut run, even where the short cut scores were too high to come within the criterion. It will be recalled that in the maze of Experiment I as well as in the present maze, the run from the starting platform to and over the short cut path was found essential for correct performance in the rest of the maze. The fact that even the short cut trials poorly executed had fewer errors than the corresponding "put on" runs points to the importance of the run from the start to the short cut path. Why was this run essential? A great disruption of the stimulus pattern, or considerable shortening of stimulus groups, we have seen, disturbs behavior. In the "put on" runs large stimulus groups were completely left out; the pattern of stimulation, though capable of considerable variation yet calling forth adequate response,

was here too greatly distorted or, more precisely, truncated by the exclusion of a large first part of the stimulus pattern. We may express the matter in mental terms by saying that the rats, in order to be able to use their knowledge of spatial relations, must be offered the elements that are to be related, that is, they must run over the element (part of the maze up to the short cut) that is to be related to another element (part of the maze beyond the short cut). Only when the two parts are thus offered can the rats perform correctly. And when the parts are offered they must, we have seen, be presented in such a way that large stimulus groups are not cut out, or, to express it in mental terms, the parts must be presented in such a way that their spatial relations are not obscured by the spatial and physical features of the short cut path.

One other point concerning "put on" runs should be considered. It will be recalled that in the maze of Experiment I, performance on a certain "put on" run suggested the possibility that the long run over unit XVIII plus the two forced turns at the ends of unit XIX may have acted as a kinaesthetic cue for the good performance beyond unit XIX. But this possibility was not borne out by other performances. Regarding the present maze, it may be asked whether, in the "put on" run that began at the left end of unit VIII ("put on" run corresponding to short cut 1-8 by a long diagonal), the encountering of corner 2 may not have presented kinaesthetic cues that re-aroused the kinaesthetic pattern and thus caused good performance in the succeeding (third) corner. Inspection of the data sheets reveals that this was not so; errors in corner 3 for this "put on" run numbered 17, whereas for the various trials of the corresponding short cut 1-8 by a long diagonal they varied from 4 to 7. We may conclude that the encountering of corner 2 from the left end of unit VIII did not produce good performance in corner 3; in other words, that no adequate kinaesthetic cues were presented. Whether the traversing of both corners 1 and 2, beginning at the upper end of unit I, would give good performance in corner 3 is a further question, but a "put on" run from this point was not tried because it did not correspond to any short cut.

DISCUSSION

Our conclusions are that rats can learn to run with a fair degree of accuracy a maze of average difficulty in the absence of specific intra- and extra-maze stimuli, that the accurate running cannot be due solely to the formation of a kinaesthetic sequence of movements, and that, in view of these facts, we may posit in rats a capacity, which may be called mental, of apprehending the spatial relations of the major parts of the maze. On the strictly behavioral side we have described the short cut performance of the rats as the capacity to respond correctly with limited modification of the stimulus pattern that is the basis of the response. This capacity, we have suggested, is the distinguishing characteristic of intelligent behavior, and may be described in mentalistic terms as the apprehension of relations of whatever sort.

Although the conclusions just stated are drawn from results on a maze in which the units were continually shifted about and from results on special kinds of runs, that is, short cut and "put on" runs, we would also assert the presence in rats of a capacity to apprehend spatial relations even in mazes which are kept constant in all respects. Indeed, such a capacity should have been guessed by experimenters long before this from results on many different mazes. Lashley⁽¹⁾ had postulated such an ability in rats in 1929: "There is clear evidence that the animals acquire some general orientation in addition to the habits of making particular turns and at present this orientation can only be described as an *abstraction** of a general direction from the diverse directions of the successive alleys." The fact, observed by various investigators, that blinds pointing in the general direction of the food are most difficult to eliminate in the learning process, points to the same sort of abstraction of general direction from diverse directions. Behavior in which such an abstraction is manifest surely cannot be rigid response to specific stimuli; there are apparent in such behavior forward-pointingness and anticipation that imply mental functions. The disproportionately large number of entrances into food-pointing blinds⁽²⁾ indicates response to a general stimulus pattern but with unfortunate minor reactions as to detail.

* *Italien ours.*

When, after a thirteen-day period during which the maze was kept constant, the units were suddenly interchanged, the result was a complete disruption of the maze habit. This pointed to the great importance of intra-maze tactual and possibly olfactory stimuli (extra-maze auditory and olfactory stimuli were found by rotation of the maze to play no significant rôle). But there is evidence from our experiment and from Lashley's investigations that reactions were made not to individual specific stimuli but rather to groups of stimuli, and, on a higher level, to patterns of groups of stimuli. We have reason to believe that tactual, olfactory, and kinaesthetic stimuli had become integrated into stimulus groups and these groups in turn into wider stimulus patterns. Response was to patterns of excitation, not to specific stimuli. Performance on short cut trials showed that within limits the pattern of excitation could be changed yet call forth adequate response. The changing of tactual and olfactory stimuli *throughout the maze*, however, disrupted stimulus groups too greatly. Tactual and olfactory stimuli that had been associated with kinaesthetic stimuli were changed when units were shifted; the kinaesthetic stimuli alone were unable to guide response correctly, and this because response had not been to kinaesthetic stimuli alone but to groups of which these kinaesthetic stimuli were parts.

With regular unit-shifting on alternate runs the error curves show a slow and jagged but nevertheless steady descent (fig. 4). The extreme slowness of the curves' descent contrasts strongly with the precipitous drop when the maze was constant. The stability of intra-maze tactual and olfactory stimuli was undoubtedly essential to rapid learning. The lack of stability prevented the formation of the stimulus groups and patterns that we postulate as the basis of response. With constant unit-shifting, integrations had presumably to be made among kinaesthetic stimuli only, and under such circumstances learning was retarded. This suggests that in general the exclusion (or rendering inoperative) of stimuli of one or more sense modalities has the effect of retarding the learning process. Tryon,⁽⁷⁾ on other evidence obtained with normal rats in an alley maze, has come to this conclusion. However, comparisons of the rates of learning of normal, blind, and anosmic rats do not in general support this.

SUMMARY

We may summarize for both experiments as follows :

1. The maze performance of blind rats that had learned an unchanged maze was greatly disturbed when the parts of the maze were interchanged, the pattern of the maze, however, remaining the same.

2. With constant and regular interchanging of maze parts, re-learning of the maze was greatly retarded, but learning was nevertheless evident.

3. There was evidence from Experiment I that interchanging of maze parts from the very beginning of training would also have retarded learning.

4. Results, in terms of error scores, when the maze was rotated and food and food box removed, strongly indicated that extra-maze auditory and olfactory stimuli played no significant rôle.

5. From the above evidence it was concluded that for blind rats intra-maze stimuli are important factors in maze learning, but that response was to integrated groups of stimuli rather than to individual specific stimuli. The question whether disturbance of maze performance following unit-shifting was due to distraction or to disturbance of stimuli that had become directive, was found to be irrelevant.

6. Results on different short cuts demonstrated that the rats were not running the maze in a purely kinaesthetic manner.

7. Because kinaesthetic running was thus disproved, and because extra-maze stimuli were found to have no influence while dependence on specific intra-maze stimuli was made impossible by constant unit-shifting, it was suggested that correct short cut performance could be attributed to a capacity of apprehending spatial relations. But in strictly behavioral terms correct short cut performance may be described as a capacity to respond adequately to a variable stimulus-pattern.

8. Differences in performance between the long-diagonal short cuts and the other short cuts, and the performance on "put on" runs, indicated the extent to which the stimulus pattern could be changed and yet produce correct response.

9. Finally, it was suggested that the distinguishing characteristic of intelligence is just this capacity, demonstrated in rats, of behaving efficiently in spite of a changing pattern of stimulation. Such behavior, viewed mentalistically, is commonly attributed to a mental function, namely, the apprehension of relations.

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